REHABILITATION OF THE HAND

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REHABILITATION OF THE HAND

By

C B WYNN PARRY
M B E , M A , D M , D PHYS MED.

Specialist in Physical Medicine, Royal Air Force

assisted by

N R SMYTHE, M A O T

Chairman of the Occupational Therapy Association,
Head Occupational Therapist, Medical Rehabilitation Unit,
Royal Air Force, Chessington

and

L E BAKER, M C S P

Superintendent Physiotherapist, Medical Rehabilitation Unit,
Royal Air Force, Chessington

with contributions from

D A BREWERTON, M D , M R C P , D PHYS MED
D BROOKS, F R C S (I)

LONDON
BUTTERWORTH & CO (PUBLISHERS) LTD.
1958

PRINTED IN GREAT BRITAIN BY R J ACFORD LTD, CHICHESTER, SUSSEX

PREFACE

COOKERY BOOKS tend to be the most irritating of all reference books. Sooner or later the phrase " cook in the usual way " brings dismay to the learner It is precisely " the usual way " that, simple as it must be to the author, is a mystery to the reader.

It may be thought that there are already enough books dealing with the hand; none to our knowledge, however, has concerned itself with detailed conservative treatment, or the niceties of after-care When the surgeon states that physiotherapy or occupational therapy should be given, following a surgical operation on the hand, it may not be clear which procedures are of help and for how long they should be maintained

This book then is an attempt to provide details of " the usual way " in the rehabilitation of hand disabilities

We have been singularly fortunate in working in the closest co-operation with, and enjoying the confidence of, the Royal Air Force Plastic Surgery Centre, under its Director, Air Commodore G H Morley, O B E , F R C S , L R C P , and the Royal Air Force Orthopaedic Service, under its Director, Air Commodore L M Crooks, O B E , M B , M CH , F R C S. We owe an especial debt of gratitude to them for their encouragement and help, for permission to publish details of their cases, and for reading the manuscript and offering helpful advice and criticism. Mr G Pulvertaft, F R C S , read the manuscript most carefully and offered numerous criticisms of extreme value, we are most grateful to him for his invaluable help We wish to thank Lieutenant-Colonel P R Wheatley, D S O , M B , B S , F.R.C S , L R C P , for much valuable criticism of the manuscript and for permission to report his cases

We should also like to thank Mr H Osmond Clarke, C B E., F R C S , for his encouragement and help, Dr H D Darcus, B M , B CH , for his help in criticizing the chapter on Anatomy and for providing the grip dynamometer, Wing Commander D M Keir, M B , CH B , F R C S (ED), Mr D Brooks, F R C S (I), Dr H Glanville, D PHYS MED , Dr F B Kiernander, M R C P , D PHYS MED , Colonel A MacMillan, M B , B S , F R C S , L R C P , Squadron Leader P J R Nichols, D PHYS MED , Dr V Wilkinson, Mr R G T. Giddens and Mr A A Armour of the Government Training Centre and Industrial Rehabilitation Unit, Waddon, for much helpful advice in the chapter on Resettlement, and Mr R. Hannand, the Resettlement Officer, Kingston Labour Exchange, who has done so much to make the resettlement of the patients possible We are very grateful also to Mr R. Carby for the drawings, Flight Lieutenant R Jane, D PHYS MED , for details of

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remedial games, and finally all the medical staff, physiotherapists, occupational therapists, remedial gymnasts and, not least, the long-suffering patients at the Royal Air Force Rehabilitation Unit, Chessington

Our thanks are due to Mrs M I Lindow for her devoted secretarial assistance Finally, we wish to thank also the Director General Medical Services, Royal Air Force, for permission to publish this book

C B WYNN PARRY

London, 1958

CHAPTER 1

FUNCTIONAL ANATOMY OF THE HAND

INTRODUCTION

THE importance of a normally functioning hand needs no emphasis, whether in earning a living, practising a hobby, or allowing independence in daily activities

The hand is capable of the strongest grasp and the most delicate touch, its rich and complex sensory innervation allows the finest judgment of texture, volume and temperature The value of a strong and well co-ordinated hand in such activities as writing, carrying, manipulating tools is obvious Less obvious perhaps is the extent to which the hand is a reflection of personality and a vital organ of expression One has only to consider the manual signs and attitudes of an oriental dancer, the benediction of a priest, the gestures of a conductor, or a Gallic raconteur, to realize how much more is the hand than a prehensile and sensory tool

Injury, disease or surgical interference, therefore, does much more than interfere with grip or touch, it attacks the personality itself In disabilities of the hand more than in any other region of the body, the finest surgery and after-care are essential Careless or inexperienced surgery, insufficient or non-existent rehabilitation are alike inexcusable Only those who have not worked with patients whose hands are seriously disabled do not realize how deep the disaster may penetrate, and how much psychological trauma, often not manifest, can be caused

All types of disease affect the hand-infections, arthritides, neoplasms, degenerations Unfortunately, the hand is also subject to injury to an alarming degree Rank and Wakefield (1953) pointed out that approximately one in three injuries requiring treatment in a casualty department involve the hand In the United States of America, of two million disabling work injuries each year, 75 per cent involve some permanent impairment of hand function

Many industrial accidents are avoidable, and more stringent safety precautions and work studies will in time decrease their incidence People will, however, continue to put their hands through window panes, knives will slip, hands will be burnt or crushed, and fingers lost

It may not be widely appreciated how much can be done for the seriously disabled hand by intensive and long-continued conservative treatment, and to what extent rehabilitation can reinforce the dexterity and ingenuity of surgery

It is accepted, of course, that the patient should be encouraged to use his hand as much as possible after tendon or peripheral nerve surgery It is less well known that with full-time rehabilitation for many months, involving much attention to detail in departments of physiotherapy and occupational therapy, the majority of patients with neurotmesis of median and ulnar nerves may obtain a hand with function not falling far short of normal

Patients with severe crush injuries resulting in stiff and contracted fingers can regain a considerable degree of function with intensive serial stretches and specialized oil massage Although this takes time, and may well involve the patient in

Clinical testing

To test the wrist flexors the patient is asked to flex the wrist slightly against the examiner's resistance applied at the level of the metacarpo-phalangeal joint of the thumb

The tendon of flexor carpi ulnaris can be seen and felt on the ulnar border of the palmar surface of the wrist and that of flexor carpi radialis can be seen and felt about one inch from the radial border of the wrist just to the radial side of the palmaris longus tendon

The palmaris longus tendon is seen and felt on wrist flexion but is best tested by asking the patient, with his wrist flexed, to touch the tip of his little finger with his thumb, when the tendon stands out boldly—it is not always present

The wrist flexors are active in almost all activities of the hand It is not possible to grade the power of each muscle accurately on the Medical Research Council scale as they work in a group

Clinically, the presence or absence of muscle action should be recorded and the power of wrist flexion, ulnar deviation and radial deviation assessed as a whole

FLEXOR MECHANISM OF THE FINGERS

Flexor digitorum profundus

The flexor digitorum profundus arises from the upper threequarters of the anterior and inner surface of the ulna, and from the interosseous membrane joining the radius and ulna It becomes tendinous about halfway down the forearm lower than sublimis (except indicis), and the four tendons pass below the flexor retinaculum at the wrist deep to the tendons of flexor digitorum sublimis

Flexor digitorum sublimis

The flexor digitorum sublimis arises from the common flexor origin, from the coronoid processes of the ulna, the ulnar collateral ligament and a thin oblique line on the outer border of the radius between the bicipital tuberosity and the insertion of pronator teres It becomes tendinous about halfway down the forearm and passes beneath the flexor retinaculum superficial to the tendons of flexor digitorum profundus The tendons destined for the index and little fingers lie deep to those for the middle and ring fingers at the wrist The tendons of both sublimis and profundus pass through the palm beneath the palmar fascia Here they are enclosed by the synovial sheaths, that of the fifth finger flexors being continuous with the synovial sheath in the flexor tunnel, and enter the flexor tunnels in the fingers The sides and roof of these tunnels are formed by the fibrous flexor sheaths which arise from ridges along the outer sides of the proximal and middle phalanges Opposite the proximal interphalangeal joints the sheath arises from the fibro-cartilaginous anterior ligament, which is grooved for the passage of the flexor tendons The tunnel stretches from the metacarpo-phalangeal joint to the insertion of the flexor profundus tendon

At the proximal phalanx the flexor sublimis tendon splits into two, allowing the tendon of flexor profundus to pass through The sublimis tendon is then reunited to be inserted, after splitting again, into the base of the middle phalanx

The profundus tendons, after splitting the sublimis tendons opposite the

several hours of treatment a day, the end-result may make the difference between returning to a skilled occupation, or taking a less skilled job, with all its financial, social and psychological implications to the patient, his family and the community as a whole

During recent years we have had an opportunity of studying and attempting to devise correct techniques of rehabilitation in a variety of hand disorders We have come to the firm conclusion that only by intensive, if necessary, full-time treatment, the utmost attention to detail, and careful and realistic planning for future occupation can the best results be obtained

The experience gained at the Royal Air Force Medical Rehabilitation Units, which has led us to realize the importance of detailed rehabilitation, is the apology for this book

The treatment of hand injuries involves the re-education of muscle action, development of muscle power and increase in joint function As intelligent treatment depends on a sound knowledge of the anatomy and function of the hand, this Chapter is concerned with the anatomy of the hand and its function For convenience, the anatomy of the muscles is described first In investigating the action of these muscles, electromyography, nerve stimulation and studies of the effects of nerve section in patients with nerve injuries have been used

FLEXORS OF THE WRIST

In flexion and extension of the wrist, movement between the two rows of carpal bones exceeds that between the radius and the proximal row of carpal bones Ulnar deviation involves movement mainly at the radio-carpal joint, radial deviation involves movement between the carpal bones themselves

Flexor carpi radialis

The common flexor origin is on the medial epicondyle, and the insertion on the palmar surface of the bases of the second and third metacarpals Its antagonist is the extensor carpi radialis longus which inserts into the dorsal surface of the base of the second metacarpal, and the extensor carpi radialis brevis, which inserts into the dorsal surface of the base of the third metacarpal The function of the flexor carpi radialis is to flex the wrist and with its antagonists to deviate the wrist radially The nerve supply is from the median nerve

Flexor carpi ulnaris

The origin is the common flexor from the aponeurosis on the upper two-thirds of the posterior border of the ulna The insertion is the pisiform bone and the base of the fifth metacarpal The nerve supply is from the ulnar nerve The function of the flexor carpi ulnaris is to flex the wrist and with the extensor carpi ulnaris to deviate the wrist in an ulnar direction

Palmaris longus

When present the palmaris longus muscle arises from the common flexor origin and is inserted into the flexor retinaculum and palmar fascia It is supplied by the median nerve Its action is to flex the wrist and tighten the palmar fascia, thus helping to cup the palm

digitorum profundus by the anterior interosseus branch of the median (tendons to index and middle fingers) and the ulnar nerve (tendons to ring and little fingers)

The lumbricals have a similar nerve supply to the flexor profundus as they arise from the tendons of that muscle The radial two lumbricals are thus supplied by the median nerve and the ulnar two lumbricals by the ulnar nerve

Action of the finger flexors

The flexors profundus and sublimis, and the lumbricals, are all concerned in flexion of the fingers The main action of the lumbricals is to flex the metacarpo-phalangeal joints and their antagonist is the extensor digitorum communis It is conventional to describe the lumbrical action as also extending the interphalangeal joints This view has been challenged by a number of workers, notably Mackenzie (1930), Wood Jones (1942) and Kaplan (1953)

Kaplan pointed out that the tendons of the lumbricals lie anterior to the transverse axis of rotation of the metacarpo-phalangeal joint They cannot slip dorsalward as they are intimately connected to the flexor tendon and thus cannot become an extensor of the interphalangeal joints Mackenzie, by a simple clinical test, concluded that the lumbricals do not extend the interphalangeal joints If the interphalangeal joints are flexed it is still possible to flex the metacarpo-phalangeal joints without extending the interphalangeal joints

Conversely, if the metacarpo-phalangeal joints are extended keeping the middle and distal phalanges flexed the interphalangeal joints can be extended without the metacarpo-phalangeal joints flexing If the lumbricals were extensors of the interphalangeal joints they would be in a state of physiological relaxation and contraction at the same time This is, of course, impossible It is concluded that the main action of the lumbricals is to flex the metacarpo-phalangeal joints Any extensor action on the interphalangeal joints is incidental and weak

The lumbricals provide two very useful actions They allow the metacarpo-phalangeal joints to be flexed independently of any activity at the interphalangeal joints as in tapping, and they reinforce the grip

The main action of flexor sublimis is to flex the proximal interphalangeal joints, when the lumbricals are paralysed the sublimis can flex the metacarpo-phalangeal joints but are not a powerful substitute for them

The main action of flexor profundus is to flex the terminal interphalangeal joint Because its tendons pass over both the metacarpo-phalangeal and proximal interphalangeal joints it will also flex these, but although it can act as a powerful flexor of the proximal interphalangeal joints in the absence of sublimis it cannot substitute powerfully for the lumbricals in gripping

The antagonists of both flexor profundus and sublimis are the interossei

Finger flexion is more powerful when the wrist is extended than when flexed, as the extended wrist allows the finger flexors to be stretched When the wrist is fully extended the fingers automatically fall into flexion, most pronounced at the proximal interphalangeal joints The fingers can be fully flexed when the wrist is extended and a full fist can be made in all positions of the wrist except full flexion

The finger flexors play little part in wrist flexion despite the fact that they cross the wrist joint. The power of wrist flexion is very little diminished when the fingers are kept extended than when they are flexed

proximal phalanges, pass to their insertion into the palmar surface of the base of the distal phalanx The alternating support thus given makes for better leverage

The two tendons lie in a synovial sheath which is indivisible from the fibrous flexor sheath

The vincula are synovial threads carrying blood vessels to the flexor tendons The vincula brevia are found in the angle between the insertion of the tendons and the phalanges The flexor sublimis has two vincula longa which arise from the tendon at the site of its splitting and are attached to the fibrous flexor sheath at its lateral borders The flexor profundus has one vinculum longum which arises from the tendon where it splits the sublimis and is attached to the roof of the synovial sheath

The flexor tunnel is only just big enough to accommodate the various structures it contains The slightest scarring after tendon suture will not allow true tendon play, and a stiff finger may result For this reason removal of both tendons and insertion of a free graft is the best treatment if one or both tendons are divided in the tunnel, unless the profundus is divided well distal to the sublimis tendon (*see* Chapter 2)

Clinical testing

To test the flexor sublimis the hand is laid flat on the desk palm upwards. The patient is asked to bend the proximal interphalangeal joint without bending the metacarpo-phalangeal or distal interphalangeal joints The proximal phalanx should be supported by the examiner

Similarly, the flexor profundus is tested by asking the patient to bend the terminal joint without bending the metacarpo-phalangeal or proximal interphalangeal joint, the middle phalanx being supported

To test the sublimis action of the ring and middle fingers the hand is laid palm upwards and the other fingers prevented from moving The patient is asked to bend the finger being tested It is impossible for the terminal joint to initiate flexion in these circumstances

Lumbricals

These small muscles arise from the tendons of flexor digitorum profundus The first arises from the radial side of the deep flexor tendon to the index finger The second from the radial side of that to the middle finger The third from both the radial side of the middle and ulnar side of the ring finger tendons, and the fourth from the radial side of the ring and ulnar side of the little finger tendons The lumbricals pass through a special lumbrical tunnel at the sides of the bases of the fingers The floor of this tunnel is the natatory ligament and the subcutaneous fat pad, and the roof is the transverse metacarpal ligament The lumbricals are inserted into the radial side of the extensor expansion of the fingers, though they have also a small insertion into the base of the proximal phalanges The lumbricals make an angle of 30 degrees in their approach to their insertion (Kaplan, 1953)

The antagonist of the lumbricals is the extensor digitorum communis

To test the lumbricals the patient is asked to bend the metacarpo-phalangeal joints without bending the interphalangeal joints

Nerve supply of the finger flexors

The flexor digitorum sublimis is supplied by the median nerve, the flexor

Abduction is the movement of the thumb away from the palm at right angles to it Adduction is the opposite movement bringing the thumb down on to the index finger There are two types of abduction, palmar and radial In palmar abduction the thumb is brought away from the index finger at right angles to it In radial abduction the thumb is brought away from the index finger at an angle of 45 degrees, being at a diagonal, and outside the plane of the palm (Fig 1)

Flexion is the movement of the thumb across the palm and in the plane of the palm

Extension is the opposite movement bringing the thumb alongside the index finger

Opposition of the thumb to one of the fingers is a complex movement comprising palmar abduction, flexion, rotation of the metacarpal towards the finger and adduction Of these four components, palmar abduction is the most important

In opposition the thumb is held abducted at right angles to the palm, the metacarpo-phalangeal joint stabilized by combined action of the long and short extensors, long abductor, and the flexors and adductors of the carpo-metacarpal and metacarpo-phalangeal joints, and the terminal joint stabilized in a variable degree of flexion by combined action of long flexor and long extensor

The extensor expansion of the long and short extensors of the thumb fuse with the fibrous flexor sheath Opposition is carried out mainly by the abductor pollicis brevis which is instrumental in opposing the thumb to the index and middle fingers, the superficial head of the flexor brevis continuing the movement to the ring and little fingers The opponens helps to rotate and flex the metacarpo-phalangeal joint

The important part played by the abductor brevis and the superficial head of the flexor can be shown by seeing and palpating these two muscles as the thumb is opposed in turn to each of the fingers This has been confirmed in two patients in whom the ulnar nerve supplied the opponens, the median supplying the short abductor and superficial head of brevis Stimulation of the median nerve at the elbow produced significantly more opposition than stimulation of the ulnar nerve

The importance of having the terminal joint of the thumb stabilized for power in opposition is reflected in the fact that all the short thenar muscles have an insertion into the extensor expansion of the thumb, so that their action of opposing inevitably results in stabilization of the terminal joint

Extrinsic Muscles Involved in Thumb Movement

Extensor pollicis longus

The extensor pollicis longus arises from the radial border of the posterior surface of the ulna below the origin of abductor pollicis longus and above that of extensor indicis, from the interosseus membrane It is inserted into the base of the radial aspect of the terminal phalanx of the thumb

It is supplied by the posterior interosseus branch of the radial nerve Its antagonists are the flexor pollicis longus and the muscles which oppose the thumb—opponens, abductor pollicis brevis and the superficial head of flexor pollicis brevis

Its action is to extend the terminal joint of the thumb, and by virtue of its ulnar-sided pull it brings the thumb round in lateral (or external) rotation to lie flat







FIG 1 —*Extension palmar and radial abduction of the thumb.*

MOVEMENTS OF THE THUMB

The main function of the thumb is to hold objects between it and the fingers

The saddle-shaped joint between the first metacarpal and the trapezium allows movement in several planes

thumb when the extensors are active, rather than to produce pure radial abduction, activity in the abductor pollicis longus always produces contraction in extensor carpi ulnaris

The muscle is tested by asking the patient to bring his thumb away at an angle of 45 degrees in a radial direction

Intrinsic Muscles

Abductor pollicis brevis

The abductor pollicis brevis arises from the flexor retinaculum, the scaphoid tubercle, and the ridge of the trapezium It may occasionally also arise from the tendon of abductor pollicis longus It is inserted into the radial side of the base of the proximal phalanx of the thumb and into the extensor expansion It is supplied by the median nerve

Its action is to abduct the thumb in the plane of the palm at right angles from the index finger, its main function being as a stabilizer

Electromyography shows that it is highly active also throughout opposition of the thumb to all four fingers It has a slight flexor action on the metacarpal and extends the terminal joint of the thumb The muscle strongly contracts in the activities of holding a pen, painting and playing the piano

The muscle is tested by asking the patient to lay the hand flat on the table, palm upwards, and to bring the thumb up at right angles to the index finger Its antagonist is the adductor pollicis

Flexor pollicis brevis

The superficial head

This arises from the flexor retinaculum and the ridge of the trapezium It is inserted into the radial side of the base of the first phalanx, and into the extensor expansion, and it has a sesamoid bone in its tendon This superficial head is supplied by the median nerve Its antagonist is the extensor pollicis brevis

The superficial head of the short flexor flexes the first metacarpal, thus bringing the thumb across the palm in the plane of the palm By virtue of its insertion into the extensor expansion it can extend the terminal phalanx weakly

To test the muscle the patient is asked to bring the thumb across the palm with the terminal joint extended

The deep head

This muscle is best considered as the first palmar interosseus Its origin, insertion, action and nerve supply are similar in all respects to the interossei

The origin is from the ulnar side of the base of the metacarpal of the thumb, and it is inserted into the ulnar side of the base of the proximal phalanx It is supplied by the ulnar nerve, and its action is to bring the radially abducted thumb to the index finger Further movement of the thumb across the palm is carried out by the deep head of the flexor brevis

To test the muscle the patient is asked to bring the radially abducted thumb towards the index finger without flexing the terminal joint of the thumb Alternatively, with the palm of the hand down on the table the patient is asked to lift

against the fingers It is also active in wrist extension and radial abduction of the thumb

To test the muscle the patient is asked to extend the terminal joint of the thumb The proximal phalanx must be supported by the examiner and the thumb held in adduction, otherwise the short abductor and flexor will also be active owing to their insertion into the extensor expansion

Extensor pollicis brevis

The extensor pollicis brevis arises from the ulnar border of the posterior surface of the radius below the origin of pronator teres, and the interosseus membrane Its tendon passes across the wrist together with that of abductor pollicis longus and is inserted into the posterior surface of the base of the proximal phalanx of the thumb

It is supplied by the posterior interosseus branch of the radial It is active in all movements connected with gripping as it stabilizes the metacarpo-phalangeal joint of the thumb Its action is to extend the metacarpo-phalangeal joint of the thumb

To test this muscle the patient is asked to extend the thumb against resistance while keeping the terminal joint flexed The tendon stands out well as the anterior boundary of the anatomical snuff box

Flexor pollicis longus

The flexor pollicis longus has an extensive origin from the anterior surface of the radius from the oblique line to just above the origin of pronator quadratus The muscle becomes tendinous in the lower quarter of the forearm and passes under the flexor retinaculum It is enclosed in a fibrous flexor sheath distal to the metacarpo-phalangeal joint, similar to those of the fingers, and inserts into the flexor aspect at the base of the terminal phalanx of the thumb It is supplied by the anterior interosseus branch of the median nerve

The flexor pollicis longus flexes the terminal joint of the thumb It has also a slight action of wrist flexion and assists in adduction when the adductor is paralysed Its antagonist is extensor pollicis longus

To test the muscle the patient is asked to bend the terminal phalanx against the examiner's resistance with the thumb adducted and the proximal phalanx supported

Abductor pollicis longus

The abductor pollicis longus arises from the middle third of the posterior aspect of the radius, the interosseus membrane and a thin line on the radial side of the posterior aspect of the ulna beneath the insertion of anconeus It becomes tendinous near the wrist, often inserting by two tendons into the radial side of the thumb metacarpal It may have two other insertions, into the trapezium or into the abductor pollicis brevis It is supplied by the posterior interosseus branch of the radial nerve

The main action of this muscle is to abduct the thumb in a radial direction, that is, at an angle of approximately 45 degrees with the index finger. It is active when objects are gripped hard between thumb and fingers Its antagonists are adductor pollicis and flexor pollicis brevis As its main action is to stabilize the

To test the muscle the patient places the hand palm downwards on the desk, and is asked to raise the little finger upwards off the desk and move it sidewards away from the ring finger This obviates the extensor digiti minimi and extensor digitorum communis deceiving the examiner by abducting as they are fully occupied in maintaining the little finger extended off the desk The antagonist to the abductor digiti minimi is the third palmar interosseus

Flexor digiti minimi

The flexor digiti minimi arises from the hook of the hamate and the flexor retinaculum and is inserted with the abductor digiti minimi

Opponens digiti minimi

The opponens digiti minimi arises from the hamate and flexor retinaculum and is inserted into the whole length of the ulnar border of the fifth metacarpal.

Both muscles are supplied by the deep branch of the ulnar nerve and their action is to flex and rotate the proximal phalanx of the fifth finger towards the thumb in opposition

Their antagonists are the extensors of the proximal phalanx of the little finger

When the thumb is opposed to the little finger the fifth metacarpal is elevated by the flexor and opponens digiti minimi and rotated towards the thumb by the same muscles The rotation is possible by virtue of the saddle-shaped joint between the fifth metacarpal and the hamate The metacarpo-phalangeal joint is stabilized by those muscles and further by the short abductor and, most important of all, the fourth lumbrical

EXTENSORS OF THE WRIST

Extensor carpi radialis longus

The extensor carpi radialis longus arises from the lower third of the lateral epicondylar ridge and the lateral intermuscular septum It inserts into the dorsal aspect of the base of the second metacarpal It is supplied by the radial nerve

Extensor carpi radialis brevis

The extensor carpi radialis brevis arises from the common extensor origin and inserts into the base of the third metacarpal It is supplied by the posterior interosseus branch of the radial nerve

The action of these muscles is to extend the wrist and acting synergically with the flexor carpi radialis to deviate the wrist radially

Their antagonist is the flexor carpi radialis which has insertions on both the second and third metacarpals to balance them

Extensor carpi ulnaris

The extensor carpi ulnaris arises both from the common extensor origin and the aponeurosis shared by flexor carpi ulnaris and flexor digitorum profundus It is inserted into the dorsal aspect of the base of the fifth metacarpal The nerve supply is from the posterior interosseus branch of the radial nerve

It is an extensor of the wrist, and working synergically with its antagonist the flexor carpi ulnaris it produces ulnar deviation of the wrist

the thumb off the table and then bring it towards the index finger, as in testing the interossei

Opponens pollicis

The opponens pollicis arises from the flexor retinaculum and the ridge on the trapezium It is inserted into the whole length of the radial border and radial half of the lateral aspect of the metacarpal of the thumb It is supplied by the median nerve and its antagonist is the extensor pollicis brevis and the long abductor and long extensor Its action is to rotate the metacarpal towards the palmar surface of the fingers

To test the muscle the proximal phalanx should be brought into abduction at a right angle to the index finger Without bending the terminal joint of the thumb the patient is asked to bring the thumb across to the tips of each finger in turn It is essential to support the thumb in abduction for the opponens cannot work effectively until the thumb is abducted If this is not done it is impossible to distinguish opponens paralysis from short abductor paralysis This is important clinically as there may be an anomalous nerve supply—the ulnar nerve supplying the opponens, or the nerve to the short abductor only may be involved

Adductor pollicis

The adductor pollicis has two heads, the oblique head arises from the palmar surfaces of the capitate, trapezoid, bases of the second and third metacarpals and the palmar ligaments, the transverse head arises from the distal two-thirds of the palmar surface of the third metacarpal The two heads are inserted into the ulnar side of the base of the proximal phalanx of the thumb There is a sesamoid bone in this tendon The muscle is supplied by the ulnar nerve Its action is to bring the thumb down to the index finger from abduction and its antagonist is the abductor brevis It is the muscle that enables objects to be firmly held between thumb and fingers

To test the muscle the patient is asked to bring the abducted thumb down at right angles to the thumb against resistance without bending the terminal joint or hyperextending the metacarpo-phalangeal joint as both the long flexor and long extensor of the thumb can act as adductors

MUSCLES OF THE HYPOTHENAR EMINENCE

It is logical to discuss the muscles of the hypothenar eminence next as their main function is to assist in elevating the fifth metacarpal and opposing the little finger to the thumb

Abductor digiti minimi

The abductor digiti minimi arises from the pisiform, pisohamate ligament and also from the tendon of flexor carpi ulnaris whose insertion is the same as the origin of the short abductor The insertion is into the base of the lateral border of the proximal phalanx of the little finger and into the extensor expansion The nerve supply is from the deep branch of the ulnar The main action is to abduct the little finger from the ring finger, but it is very active in opposition of the thumb to the little finger when it stabilizes the metacarpo-phalangeal joint It is also a weak extensor of the little finger The flexor carpi ulnaris always contracts to stabilize the ulnar border of the wrist when the abductor digiti minimi contracts

border of the fifth metacarpal The palmar interossei insert both into the extensor expansion and the base of the proximal phalanx of the finger from which they take origin All the interossei are supplied by the deep branch of the ulnar nerve

Owing to their double insertion the interossei have two functions both the palmar and dorsal interossei extend the interphalangeal joints, and their antagonists are thus the flexors sublimis and profundus Bunnell (1956) stated that the interossei will flex the metacarpo-phalangeal joints when the dorsal sleeve is lax, but this is not borne out by electromyographic investigation No activity is seen in the interossei when the metacarpo-phalangeal joints are flexed, but much activity when the fingers are extended or abducted

The dorsal interossei abduct the fingers and the palmar interossei adduct them The middle finger, being the reference point, has no palmar interossei

All the muscles that separate and bring the fingers together—interossei and abductor digiti minimi—are supplied by the ulnar nerve

To test the interossei the patient is asked to place the hand palm down on the desk Each finger in turn is then raised off the desk and the patient is asked to abduct and adduct the finger No other muscle can substitute for this action in the middle and ring fingers The trick action of extensor digitorum communis is not possible as this muscle is fully occupied in raising the finger off the desk

The index and little fingers each have an extra extensor

Extensor indicis proprius

The extensor indicis proprius arises from the radial border of the posterior surface of the ulna below the origin of extensor pollicis longus and is inserted to one side of the extensor communis tendon to the index finger, in the extensor expansion

Extensor digiti minimi

The extensor digiti minimi arises from the common extensor origin and is inserted into the extensor expansion of the little finger

Both muscles are supplied by the posterior interosseus branch of the radial nerve

As the index and little fingers have two extensors, some abduction is possible in these fingers when the interossei are paralysed (*see* Chapter 3)

The main function of the extensors of the fingers is to extend the metacarpo-phalangeal joints, and by virtue of their attachment at these joints they have normally little or no extensor action on the middle and distal phalanges When the metacarpo-phalangeal joints are stabilized, however, they can exert some extensor action on these joints When the capsule of the metacarpo-phalangeal joints is loose, as is sometimes seen in patients, then the extensor digitorum can extend the interphalangeal joints as well as the metacarpo-phalangeal joints Normally, however, the interphalangeal joints can be extended while the metacarpo-phalangeal joints remain fully flexed When the metacarpo-phalangeal joints are fully flexed it is almost impossible to abduct the fingers owing to the tightening of their collateral ligaments The provision of separate flexors and extensors for the metacarpo-phalangeal and interphalangeal joints makes for much greater freedom and independence of action in the hand Many activities of the hand require metacarpo-phalangeal flexion and interphalangeal extension at the same time, and vice

The wrist extensors always contract strongly to stabilize the wrist and provide greater leverage when the fingers are flexed The power of grip is poor when the wrist is fully flexed

To test these muscles the patient is asked to extend the wrist with the metacarpo-phalangeal joints flexed If the muscles are weak, the wrist must be supported in extension The tendons can be seen and felt at the wrist

EXTENSOR MECHANISM OF THE FINGERS

The extensor digitorum communis arises from the common extensor origin and divides into tendons, one for each finger, in the lower third of the forearm The tendons form the extensor expansion on the dorsal surface of the phalanges

Opposite the metacarpo-phalangeal joint the extensor tendon becomes the dorsal ligament of the joint by virtue of fasciculi connecting it to the lateral ligaments Over the dorsal surface of the phalanges it forms an aponeurosis—the so-called extensor expansion This is reinforced by fibrocartilage opposite the joints The expansion divides into three slips, a central slip inserting into the base of the middle phalanx and two lateral slips inserting into the sides of the distal phalanx of each finger Laterally the expansion has an attachment to the fibrous flexor sheaths of the fingers At the base of the proximal phalanx there is a refinement of the tendinous expansion known as the " sleeve " This is a band of transverse fibres across the dorsal surface of the proximal phalanx which becomes blended beneath with the capsule of the joint When the extensor tendon is relaxed the sleeve lies on the dorsal surface of the proximal phalanx When the extensor tendon is contracted, the sleeve is pulled up so as to be over the metacarpo-phalangeal joint When the sleeve is slack the lumbricals can flex the metacarpo-phalangeal joints When the sleeve is pulled up by the extensor digitorum the lumbricals cannot act as flexors and have a weak extensor action on the fingers

The lumbricals have their main insertion into the lateral border of the extensor expansion

The antagonists of the extensor digitorum communis are the lumbricals

The interossei:

There are four dorsal interossei, the first of which arises from the adjacent borders of the first and second metacarpals and is inserted into the base of the proximal phalanx and into the extensor expansion more laterally

Similarly, the second and third dorsal interossei arise from adjacent borders of the second and third and third and fourth metacarpals and insert both into the extensor expansion and on either side of the base of the proximal phalanx of the middle finger The fourth dorsal interosseus arises from adjacent sides of the fourth and fifth metacarpals and is inserted into the base of the proximal phalanx of the fourth finger and the extensor expansion

The palmar interossei are also four in number if the deep head of flexor pollicis is considered as the first palmar interosseus

The second arises from the ulnar border of the second metacarpal, the third from the radial border of the fourth metacarpal, and the fourth from the radial

nerve supply to the palm of the hand is remarkably constant In some 5 per cent of patients with peripheral nerve injuries, the median or ulnar nerve supplied the whole of the ring finger Otherwise, anomalous sensory innervation was rare although wider variations are described One patient was seen in whom the ulnar nerve supplied the little finger, the ring finger, and the ulnar half of the middle finger In this patient the ulnar nerve supplied all the hand muscles except abductor pollicis brevis

The median nerve divides into lateral and median branches after piercing the flexor retinaculum The lateral branch supplies the short muscles of the thumb and then gives off three digital branches, two to the thumb and one to the radial side of the index finger The medial branch divides into two digital branches, one supplying the ulnar side of the middle finger and the radial side of the ring finger This branch anastomoses with the ulnar nerve The digital nerves also communicate with the radial nerve on the dorsal surfaces of the proximal phalanx The ulnar nerve divides into superficial terminal and deep terminal branches beneath the flexor retinaculum The deep terminal branch is a motor nerve to the hypothenar eminence, third and fourth lumbricals, interossei, adductor pollicis and deep head of the flexor pollicis brevis The superficial terminal branch divides into two branches, one supplying the ulnar border of the little finger and the other the radial side of the little finger and the ulnar side of the ring finger

The palmar cutaneous branch of the median arises in the lower part of the forearm and supplies the skin of the thenar eminence where it anastomoses with the radial nerve and the skin of the palm

The palmar cutaneous branch of the ulnar nerve arises about the middle of the forearm and supplies the skin of the palm communicating with the median nerve

On the dorsal aspect of the hand the terminal phalanx of the thumb, the middle and distal phalanges of the index and middle fingers, and the radial half of the middle and distal fingers are supplied by the median nerve

The ulnar nerve supplies via its palmar digital branches the dorsal surface of the ulnar side of the middle and distal phalanges of the ring finger and the dorsal surface of the distal phalanx of the little finger By its dorsal branch and via these digital branches the ulnar nerve supplies the fifth metacarpal and proximal and middle phalanges of the fifth finger and the ulnar half of the proximal phalanx and metacarpal of the ring finger It communicates with the radial nerve

The rest of the back of the hand is supplied by the median and radial and occasionally the ulnar nerves, the exact supply is very variable In most people the radial nerve only supplies autonomously skin over the first dorsal interosseus space—severance of the radial nerve often results in no loss of sensation in the hand at all The sensory distribution in the hand is shown in Fig 2

Physiology of sensation

Earlier workers described two types of sensation—crude or protopathic and fine or epicritic Return of sensation after peripheral nerve injuries was supposed to be in two stages—protopathic first and later epicritic This theory no longer holds its ground, the intensification of sensation in the early stages of nerve regeneration, or so-called protopathic sensation, is now believed to be due to

versa—writing, drawing, manipulating small tools, and so on The connexion of the extensor expansions and flexor sheaths allows of this most important co-ordination between the flexor and extensor muscles

POSITION OF FUNCTION

When the hand has to be immobilized for any reason—in plaster after fractures, in splints during the acute stages of poliomyelitis, in bandages and splints after operation—there is an optimum position of the hand in which, if stiffness does develop, it will function better than in any other

The wrist should be in 20 degrees dorsiflexion, the metacarpo-phalangeal joints in some 45 degrees flexion (at 135 degrees), the proximal interphalangeal joints in 30 degrees (at 150 degrees), and the distal interphalangeal joints in 20 degrees flexion (at 160 degrees) The thumb should be in half palmar abduction and half opposition, the interphalangeal joint in a few degrees of flexion

The elbow should be in 90 degrees flexion and the mid-prone position and the shoulder in 45 degrees abduction, 30 degrees flexion and in neutral rotation

ANOMALOUS INNERVATION

The innervation of the intrinsic muscles of the hand varies from the classical description more frequently than is generally realized Seddon (1954) found that variations occurred in 20 per cent of 226 cases of peripheral nerve injuries studied Every gradation is found from complete ulnar nerve supply to complete median innervation of the intrinsic muscles The commonest variation is in the supply of flexor pollicis brevis In one-third of cases the ulnar supplies both heads, in one-third the median, and in one-third there is a double innervation The median nerve can supply the third lumbrical, and in some 10 per cent of cases we have seen, the ulnar nerve has supplied the opponens Occasionally, the nerve supplying abductor pollicis brevis or the opponens, or both, takes a very tortuous course beneath the skin on emerging from under the flexor retinaculum It is thus exposed to trauma and explains the puzzling phenomenon of isolated short abductor or abductor and opponens palsy sometimes seen

It is extremely rare for anomalies to involve the radial nerve though radial supply of the dorsal interossei has been described

To test for the presence of anomalous innervation the median and ulnar nerves are stimulated at the elbow and wrist, and contraction looked for in the hand muscles It is necessary to stimulate at the elbow as well as the wrist, for the nerve supply to the interossei may occasionally travel to the elbow in the median nerve and then cross over to the ulnar in the forearm Other electrodiagnostic methods will reveal anomalous innervation—plotting strength duration curves, or electromyography, will reveal the presence or absence of denervation If these methods should fail, nerve block with local anaesthesia will help to elucidate the problem

SENSATION

The hand is a most important sensory organ and its skin, particularly on the palmar surface, is richly supplied with all types of sensory receptor. In our experience the

Pain

Pain is tested by applying a sharp needle perpendicularly and at a constant pressure over the skin to detect the dividing line between present and absent or altered sensation The needle is dragged slowly and at a uniform pressure across the skin The test should be repeated before the area of pain sensitivity is finally mapped out

Touch

A Von Frey's hair is the most accurate method of testing touch, though cotton-wool if used carefully and with a fine applied tip may be adequate

Joint sensation

Each joint is moved several times with constant pressure in all directions, the joints above and below being supported by the examiner The patient is asked to say which joint is being moved and in which direction This test should be explained carefully to the patient and demonstrated first on the unaffected hand A record should be made of whether the patient detects fine or only gross movements, and in what proportion of tests he is correct in judging the direction

Vibration sense

Vibration sense is tested by the response to the tuning fork

Two-point discrimination

A compass is used to measure the least distance between the two points at which the patient can feel two and not one prick Comparable areas on the normal hand should be tested and measurements made, because this modality varies in different people and is said to vary in different occupations Table I shows the values for normal found by the author in 50 young male subjects, the values did not seem to bear any relation to occupation

Temperature

Elaborate systems of temperature measurement are not called for The surface of a clinical tuning fork is adequate for testing cold sensation and a test tube of warm water for heat

Stereognosis

Various objects, such as buttons, coins, safety pins, rubbers, keys, are put into the patient's hand and he is asked to describe them An estimate of the time taken in recognition and the number of correct answers is useful in the assessment of recovery

In testing for all types of sensation the patient must be asked to describe what he feels as accurately as he can, particular attention being paid to added sensation or altered response

When testing for touch the patient must be asked to say if the sensation is that of touch, pressure, tinglings, or a numb sort of feeling Similarly, when testing for pain, inquiry should be made into the presence of excess pain, or a feeling of pressure only

Sweat tests

These may occasionally be useful when it is difficult to map out the area of sensory loss in a patient The dye method involves applying quinazarin powder to the affected limb and heating the patient in a special hot chamber. When the

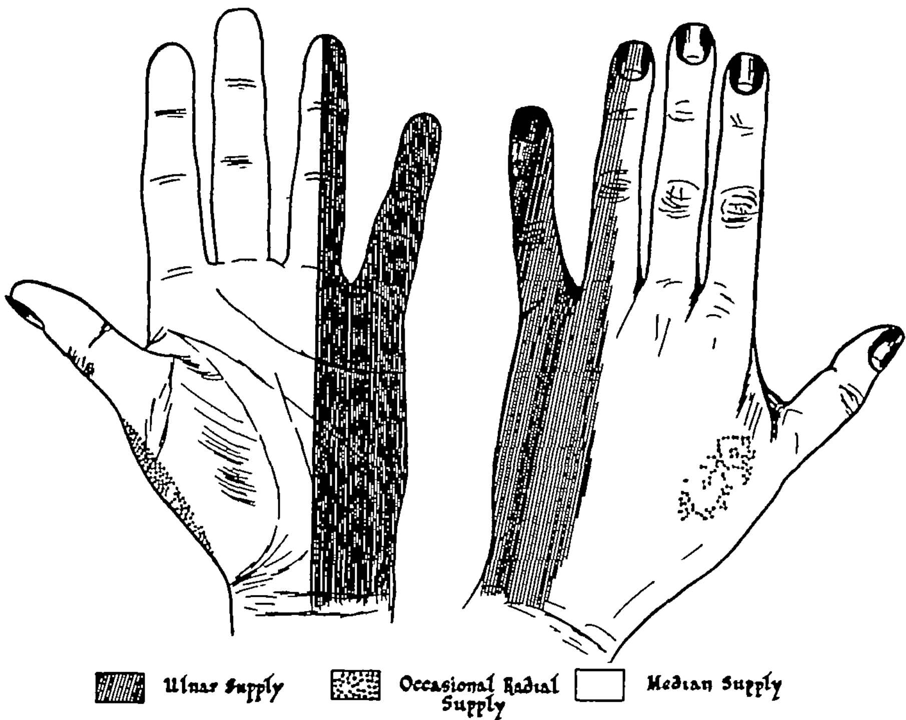


FIG 2 —*Sensory supply of the hand as deduced from clinical studies in peripheral nerve injuries*

lack of insulation of the growing nerve fibres which disappears as they acquire their myelin sheaths

There are four primary modes of sensation—touch, pain, cold and warmth "The relation of light touch to painless pressure remains obscure" (Walshe, 1942) As Walshe pointed out, pressure may derive from the activity of both cutaneous and deep sensory mechanism, it is a concept rather than a primary sensation

Similarly, two-point discrimination is a judgment, not a primary sensation, and to some extent depends on the patient's intelligence

In a peripheral nerve injury, testing for sensation reveals two areas of sensory disturbance An outer area where sensation is diminished but not absent (due to adjacent nerves overlapping) and an inner area where it is completely lost Normal skin does not respond to temperatures within 5° F of the skin temperature Thermal hypo-aesthesia consists in widening of the indifferent range and diminished intensity of thermal sensation (Walshe, 1942)

Trotter, quoted by Walshe (1942), pointed out that there is transitory hyperalgesia for some hours after nerve section, then for 10 days it disappears, only to re-appear for 6 weeks and then disappear entirely

Clinically, all modalities of sensation should be tested—pain, touch, joint sensation, temperature, stereognosis, and two-point discrimination The patient should first be asked to indicate the affected area, and to say if feeling is completely absent, diminished, excessive or altered

TABLE II

AVERAGE RANGE OF MOVEMENT IN NORMAL PROXIMAL INTERPHALANGEAL JOINTS AND NORMAL METACARPO-PHALANGEAL JOINTS
(by degrees)

Joints	*Preferred hand*			*Non-preferred hand*		
	Skilled	*Sedentary*	*Heavy*	*Skilled*	*Sedentary*	*Heavy*
Proximal interphalangeal						
Index	105	107	100	106	106	103
Middle	103	106	103	102	104	102
Ring	104	109	105	108	107	105
Little	100	105	100	101	102	100
Metacarpo-phalangeal						
Index	86	84	82	84	84	79
Middle	87	87	86	88	87	85
Ring	85	87	86	85	86	84
Little	87	87	89	89	86	88

TABLE III

LIMITS OF NORMAL RANGE OF MOVEMENT IN PROXIMAL INTERPHALANGEAL JOINTS AND METACARPO-PHALANGEAL JOINTS
(by degrees)

Joints	*Preferred hand*			*Non-preferred hand*		
	Skilled	*Sedentary*	*Heavy*	*Skilled*	*Sedentary*	*Heavy*
Proximal interphalangeal						
Index	90-130	90-125	90-115	90-130	80-120	85-115
Middle	90-115	90-130	90-125	90-125	90-120	80-115
Ring	75-120	90-125	90-125	90-135	90-126	80-120
Little	70-120	85-150	85-120	85-125	90-130	90-115
Metacarpo-phalangeal						
Index	75-95	70-95	75-90	70-95	60-95	70-90
Middle	80-100	80-95	70-95	80-100	65-95	75-90
Ring	75-90	75-95	75-95	75-95	80-100	70-95
Little	75-95	65-95	70-95	75-100	75-105	80-100

TABLE IV

AVERAGE RANGE AND LIMITS (in parentheses) OF MOVEMENT IN NORMAL DISTAL INTERPHALANGEAL JOINT
(by degrees)

	Preferred hand			*Non-preferred hand*		
	Skilled	*Sedentary*	*Heavy*	*Skilled*	*Sedentary*	*Heavy*
Index	72 (55-90)	72 (55-90)	71 (60-90)	73 (45-85)	74 (60-90)	73 (60-95)
Middle	75 (60-100)	75 (65-95)	70 (65-90)	76 (45-90)	78 (65-95)	75 (50-95)
Ring	73 (55-95)	73 (55-90)	70 (60-85)	73 (45-90)	73 (60-95)	70 (50-90)
Little	76 (60-90)	73 (50-90)	77 (60-90)	79 (55-95)	79 (55-85)	76 (50-85)

TABLE I

TWO-POINT DISCRIMINATION IN THE HAND

(measured in millimetres figures in parentheses denote extremes)

Site	*Thumb*		*Index*		*Middle*		*Ring*		*Little*	
	Dorsal	*Palmar*	*Dorsal*	*Palmar*	*Dorsal*	*Palmar*	*Dorsal*	*Palmar*	*Dorsal*	*Palmar*
Terminal phalanx	2 5 (1-6)	2 75 (1 5-2 75)	3 5 (1 5-6)	2 25 (0 5-4)	2 75 (1-7)	2 (1 5-3)	4 (1-12)	2 5 (0 5-4)	3 5 (2-6)	2 5 (0 5-5)
Middle phalanx			3 5 (0 5-5)	3 3 (1-6)	3 1 (1-8)	3 25 (1-6)	3 (1-7)	5 (2 5-7)	4 (2-8)	2 5 (2-6)
Proximal phalanx	4 25 (1-9)	4 5 (2 5-7)	4 5 (1-12)	5 (3 5-8)	3 (1-7)	5 (2-8)	3 5 (0 5-10)	4 5 (2-6)	2 5 (0 5-4)	4 5 (2-8)
Thenar eminence										
Base		3 75 (1-6)								
Middle		11 (10-13)								
Distal crease				6 (5 5-7)		6 (3 5-8)		8 (3-10)		4 (2 6)

Mid-palm 9 (4-15) Hypothenar eminence middle, 7 (5-9), base, 3 (1-3 5)

dye changes colour to deep blue, sweating is present Where sweating is absent no change in colour occurs Alternatively, the skin resistance may be measured by electrical means High values indicate absence of sweating as the skin resistance is always higher in dry than moist skin

The sensory innervation and sweat distribution are by no means always coincident

JOINT RANGE

The range of movement of the metacarpo-phalangeal and interphalangeal joints is said to depend very much on the patient's occupation and age It is always advisable to note the range of movement in the equivalent unaffected joints when examining joints with a limited range of movement

When testing joint range a small goniometer in the form of a protractor with moveable arrow indicators is used (Fig 3)

Tables II to V give the range of movement of flexion and extension in the joints of the finger and thumb found by the author in 100 normal young adult males It is remarkable how little trade and laterality affect the range of movement

The amount of movement in the finger joints required for various activities is discussed on page 19

GRIP

Apart from the long flexors of the fingers and thumb, the lumbricals and wrist and finger extensors are of great importance as stabilizers in gripping

During recovery in an ulnar or median nerve lesion, the value of grip increases markedly when the lumbricals begin to recover Similarly, in a radial nerve palsy the power improves greatly as the wrist and metacarpo-phalangeal extensors recover

Commonly, the grip is only 20 per cent of normal when the wrist and finger extensors are paralysed

A simple bulb dynamometer is quite adequate to judge the power and progress of grip. It consists of a rubber bulb 2½ inches in diameter and 3 inches in length, attached to an air-pressure gauge measuring 0 3 lb per square inch The bulb and air-pressure gauge contain hyraulic oil, and the dynamometer is finally filled with air introduced through a tap on a stem between the bulb and pressure gauge

The patient is asked to grip the bulb as hard as he can while the examiner supports the instrument round the stem Three readings are taken at intervals of 15 seconds The difference in the readings between the normal and the affected hand is recorded, thus allowing for changes in the pressure with use Both hands should always be tested as the power of the unaffected hand invariably improves with treatment, it is the difference between the two hands which is of significance

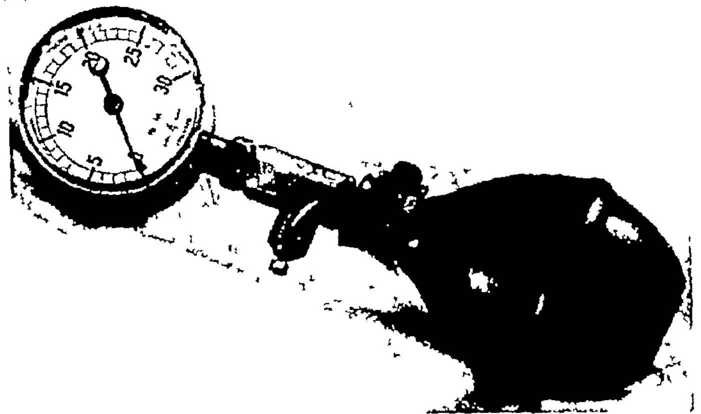


FIG 4 —*Dynamometer for measuring the power of grip.*

Fig 4 illustrates the type of dynamometer used by the authors Table VI shows the value of grip in 100 young male adults Wainerdi (1950) found values of 13–19 lb for women and 15–22 lb for men

There is surprisingly little difference between the grip using the fingers alone, and the ball of the thumb alone, and between the left and the right hands The grip fatigues extremely quickly, therefore, a simple fatigue test is worthwhile in patients

TABLE VI

AVERAGE VALUES FOR GRIP (lbs per square inch) AND LIMITS OF NORMAL (in parentheses)

Preferred hand			*Non-preferred hand*		
Skilled	*Sedentary*	*Heavy*	*Skilled*	*Sedentary*	*Heavy*
15 (9-15)	14 7 (11-18)	14 3 (6-19 5)	15 (9-21)	14 (12-17)	14 (11-18)

TABLE V

AVERAGE RANGE AND LIMITS (in parentheses) OF MOVEMENT IN NORMAL INTERPHALANGEAL JOINT OF THUMB
(by degrees)

Preferred hand			*Non-preferred hand*		
Skilled	*Sedentary*	*Heavy*	*Skilled*	*Sedentary*	*Heavy*
90 (65-115)	97 (65-135)	89 (70-120)	88 (70-110)	91 (65-110)	88 (65-105)

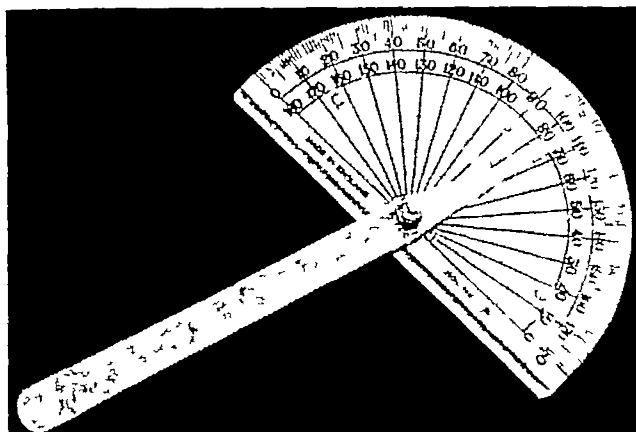


FIG 3 —*Goniometer for measuring finger movements*

When measuring joint range the values from full extension to full flexion possible both actively and passively must be recorded, for example, the following measurements might be recorded following tendon grafting

Index finger, left hand

Terminal interphalangeal joint	Active	170/150	=	20 degrees of flexion
	Passive	170/90		
Proximal interphalangeal joint	Active	150/120	=	30 degrees of flexion
	Passive	150/70		
Metacarpo-phalangeal joint	Active	170/90	=	80 degrees of flexion
	Passive	170/80		

Not as one often sees recorded

Terminal interphalangeal joint	20 degrees	(80 degrees passive)
Proximal interphalangeal joint	30 degrees	(80 degrees passive)
Metacarpo-phalangeal joint	80 degrees	(90 degrees passive)

When an increase in range is recorded the latter method does not allow one to judge if the flexion deformity is being overcome or if further flexion is occurring due to increased excursion of the tendon, or both

When there is limitation of movement in the metacarpo-phalangeal or carpo-metacarpal joints of the thumb, the range of maximum palmar abduction should be measured in centimetres to get a value of the web stretch, and flexion and extension measured by the distance the thumb with the interphalangeal joint extended can flex and extend from the index finger Opposition can be roughly measured by taking the angle the thumb pad makes with the horizontal, abduction and adduction can be measured passively by taking the distance between the proximal end of the nails of two adjacent fingers

Grip

In grip the fingers are flexed towards the palm, the thenar muscles acting as stabilizers It is primarily an action of the long flexors and lumbricals, but the long flexors alone can be concerned, as in carrying a suitcase (Of 120 people observed leaving a station platform 101 were using the index, middle and ring fingers only, with the thumb laid across the top of the handle of the suitcase and the little finger curved slightly under the handle, but taking little part in the carrying process) When the movement is carried to its conclusion both the thenar and hypothenar muscles are used, and the object is held firmly in the carpal and metacarpal arches of the hand, which are essential to most types of grasp (Fig 5 *a* and *b*)

Too often the part played by the hypothenar group is forgotten and there is failure to re-educate these muscles These are important in strength of grip and can in some measure compensate for inadequate activity of the thenar muscles after injury

Pinch

The second of the prehensile movements involves a fine control of the fingers in digital grasp, when the thumb is opposed to one or more of the fingers By this movement objects as small as a pinhead or as large as a cricket ball can be held between the ball of the thumb and finger-tips For this reason amputation of the thumb, or loss of thumb function, is one of the most crippling disabilities.

The finest of these movements is between the balls of the index finger and thumb and the ring finger and thumb If a very light pinch grip on a delicate object is required, it is often the ring finger which is opposed to the thumb, for the fourth metacarpal has no muscle attached to its base, thus giving it a resilience and range that the other metacarpals lack (Fig 5 *c*)

It is important to note that the heads of the metacarpals of the ring and little fingers are elevated in the performance of these movements, in order to appreciate this loss of function in conditions affecting the intrinsic muscles of the hand, such as lesions of the ulnar nerve

Sensation

Movements are all performed against a sensory background. In any disability of the hand the periphery is disturbed, and either there is no sensory inflow to the central nervous system, as in a peripheral nerve palsy, or an abnormal inflow as in causalgia or a regenerating nerve

When the inflow is painful the disturbance can be very profound, and if persisting for long the result can be a new sensorial pattern of the hand in the central nervous system

A child is so rapidly changing sensory patterns that an abnormal pattern is quickly lost, but adults do not readily lose abnormal patterns, and the importance of re-education cannot, therefore, be over-estimated

The ability to recognize the shape, texture, weight and temperature of objects is just as important a function of the hand as movement and grasp It is impossible to carry out any fine work with loss of sensation in the median nerve A lesion of the sensory branch of the median nerve is a worse disability than a complete lesion of the ulnar nerve

who require endurance of grip for their job In this test the patient grips maximally every 5 seconds until the value drops below 50 per cent of the initial reading The number of grips applied before this occurs is recorded and an increase shows improvement

SUMMARY OF MUSCLE FUNCTION IN THE HAND

Flexors of fingers
Metacarpo-phalangeal joint—lumbricals
Proximal interphalangeal joint—flexor digitorum sublimis
Terminal interphalangeal joint—flexor digitorum profundus

Extensors of fingers
Metacarpo-phalangeal joint—extensor digitorum communis
Proximal interphalangeal joint } interossei (and lumbricals—weak action)
Terminal interphalangeal joint }
Abduction and adduction of fingers—interossei
Rotation (opposition of thumb)—abductor pollicis brevis, flexor pollicis brevis, opponens

Grip
Long finger flexors, lumbricals, interossei, metacarpo-phalangeal joints stabilized by extensor digitorum communis
Wrist flexors and extensors contracting to stabilize the wrist

SUMMARY OF NERVE SUPPLY TO MUSCLES

Ulnar nerve in the hand
Hypothenar group—abductor, flexor and opponens digiti minimi
Third and fourth lumbricals
All interossei
Adductor pollicis
Half flexor pollicis brevis (deep head)
(All have root supply C 8 T 1)

Median nerve in the hand
Thenar group—opponens pollicis, abductor pollicis brevis, half flexor pollicis brevis (superficial head)
First and second lumbricals
(All have root supply C 8 T 1)

Radial nerve
Triceps (C 6, 7)
Brachioradialis (C 5, 6)
Extensor carpi radialis longus (C 6, 7)

Posterior interosseus nerve
Supinator (C 5, 6)
Extensor carpi radialis brevis (C 6, 7)
Extensor carpi ulnaris (C 7, 8)
Extensor digitorum communis (C 7, 8)
Extensor pollicis longus (C 7, 8)
Extensor pollicis brevis (C 7, 8)
Abductor pollicis longus (C 7, 8)

FUNCTIONS OF THE HAND

It is difficult to classify the many functions of the hand, but they can be considered under the broad headings of (1) prehension, (*a*) crude as in grip, (*b*) fine as in pinch, (2) sensation.

Prehension

Prehension is the act of grasping or holding an object, and can be divided into two types, grip and pinch

support or balance This is the position of writing, painting, dissecting, needlework, manipulating forceps and small screw-drivers

Many actions of this nature are aided in balance by the little finger, which will often steady a delicate movement performed by the others, it can be readily understood, therefore, why the abductor minimi digiti is a larger and more powerful muscle than the abductor of the ring finger This is well demonstrated when manipulating an object with the ring, middle and index fingers and thumb while supporting the hand with the little finger It is much more difficult to support the hand with the ring finger, and balance is even more difficult to achieve if the movement being performed is delicate and long drawn out It is wise then to realize when amputation is contemplated how important is the function of the little finger Certainly, serious consideration should be given to the patient's type of work before such a radical measure is carried out

The metacarpal arch is of particular importance in this type of hand function, as can be seen when the fingers manipulate, for instance, a pair of laboratory forceps The ring finger is held well in front of the little finger In this dynamic tripod position, the metacarpo-phalangeal joints are flexed whilst the interphalangeal joints are flexing and extending This action is primarily one of the intrinsic muscles and depends on a nice balance between lumbricals and interossei

It can be observed that the more delicate the function the more interphalangeal extension there will be in the ring and little fingers, furthermore, as the muscles controlling the tripod attempt to steady for a very delicate poise, the stronger will be the contraction of abductor minimi digiti If the insertion of flexor carpi ulnaris is palpated it will be seen how strongly this muscle is working as a fixator of the wrist This is particularly apparent when the hand is partially supinated and working in ulnar deviation, such as under-cutting in dissection

The planes of the metacarpal heads form a triangle, the base lying between the thumb and the fifth metacarpal head, one side lying between the thumb and the fifth metacarpal head, one side lying between the thumb and the index finger, and the third side forming a curved oblique line between the index finger and the fifth metacarpal head These are important facts to appreciate when putting a hand or wrist in plaster, or designing physiological splints, especially when deformity is caused by muscle paralysis and these planes are altered or lost altogether

In certain activities the triangular plane of the hand broadens out and the base of the triangle widens The tripod weakens and all 5 fingers assume dynamic function These include draughtsmanship, piano playing, typing, playing some musical instruments such as the harp, machining and feeding flat materials into machines

To obtain the maximum span between the first and fifth finger, the wrist will assume a position of palmar flexion. Light delicate work involving a free movement of all fingers with the metacarpo-phalangeal joints in various degrees of extension will be most easily observed with the wrist in the neutral position When a more stable movement is required the wrist will extend, the metacarpo-phalangeal joints flex, and the fingers adduct and extend.

The labourer's position, or palmar grasp

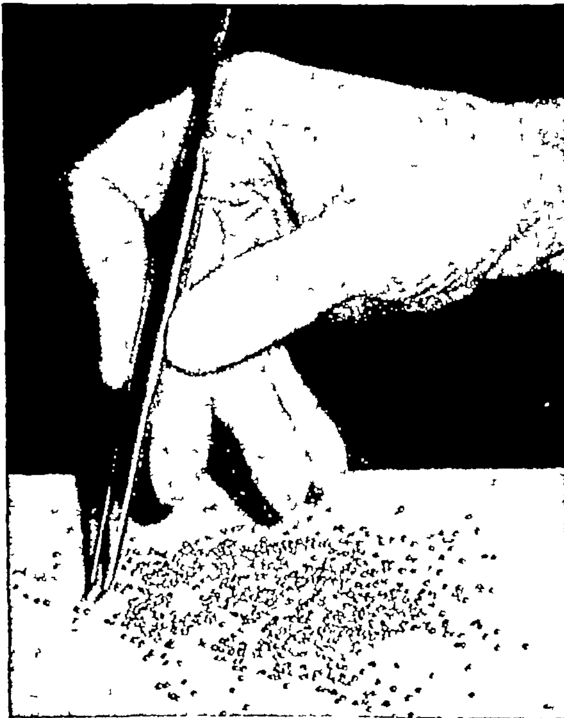
This is the position for firm grasp of objects Direction is given by the first



(*a*)



(*b*)



(*c*)

FIG 5—*Types of grip* (a) *light grip,* (b) *heavy grip,* (c) *pinch grip*

Patterns of function

The activities of the hand use, in the main, two positions· (1) the scribe's position, and (2) the labourer's position.

The scribe's position

The scribe's position is that assumed by the thumb, index and middle fingers when used as a dynamic tripod with the ring and little fingers acting as a

CHAPTER 2

INJURIES TO TENDONS

FLEXOR TENDONS

THE ANATOMY of the flexor tendons was described in detail in Chapter 1, but it will be recalled here that there is a very small space between the metacarpophalangeal joint and the proximal interphalangeal joint in which the sublimis and profundus tendons glide In the palm there is more room for the tendons to move and greater elasticity of the surrounding tissues, so that injuries of the tendons at this site are less likely to result in adherence At the wrist there is plenty of space surrounding the tendons and damage here is less likely to cause adherence than in the palm Owing to the confined space in which the tendons move in the finger itself, injuries to the finger tendons are far more disabling and present much greater problems than in the palm or at the wrist

INJURIES OF THE FLEXOR TENDONS AT THE WRIST

Causative factors

The commonest cause of tendon injuries at the wrist is a fall on glass, or on sharp objects such as stones, metal, and the edges of tins Accidents with knives are fairly common, as are the results of plunging the hand through a window pane Patients who sustain injuries to the flexor tendons through window panes usually damage one or other of the nerves and almost invariably the ulnar or radial artery

Frequency

The commonest tendons to be affected in order of frequency are the palmaris longus, the flexor carpi radialis, flexor carpi ulnaris, sublimis and profundus tendons of the fingers The ulnar artery is often involved with the tendon injury When the nerves are affected the tendons involved depend on which nerve is severed In our series of nerve injuries at the wrist, the commonest tendons to be involved with an ulnar nerve lesion were the flexor carpi ulnaris, the flexor profundus and flexor sublimis to the fourth and fifth fingers, the ulnar artery was involved almost as commonly When the median nerve was affected, the commonest tendons to be involved were the flexor pollicis longus, the flexors of the index fingers, the flexor carpi radialis and the palmaris longus When both median and ulnar nerves are affected, it is usual for most structures in front of the wrist joint to be severed It is unusual to have a nerve injury at the wrist without tendon involvement, but it is quite common to have tendon injuries without nerve involvement

Treatment

Single tendon

The surgical treatment of choice for tendon injuries at the wrist is immediate suture The wrist should be kept at rest in mild flexion for 3 weeks, after which time active exercises may be commenced

two fingers and thumb, or the index finger and thumb, whilst balance and stabilization are controlled by the middle, the ring and the little fingers flexing round the object The middle fingers will assume direction, assist with stabilization or provide a balance between both

All small tools, and most large tools, require this kind of control, and objects of any length, although they may require delicate manipulation, need part of the palmar grasp to stabilize the extra length, Weight may be taken on the hypothenar eminence across the pisiform bone, and the tool will lie in an oblique line

The physiological movements of the hand and wrist when assuming lateral positions is towards extension when radially directed, and towards wrist flexion when moved ulna-wards These will be modified by peripheral fixation but are influenced by the passive elastic forces of the hand and wrist (These points are significant when planning exercises, lively splints and gadgets for the handicapped hand and arm)

Tools may be directed towards the radial or ulnar borders of the hand and both may travel through an arc from radial to ulnar positions, such as a hammer held in a radial direction, or a chisel pointing in the ulnar direction

The fundamental working positions of the fingers and hands are determined, to a large extent, by the passive elastic forces, for instance, a strong grip is more easily maintained in the mid-prone position than in complete pronation and requires some wrist extension for efficiency Wrist flexion and extension are also more easily carried out in the mid-prone position than in full pronation

When the object is large or heavy, all the fingers are flexed towards the palm, and the thenar and hypothenar muscles grip the object or the fingers round it Direction of movement is controlled by the wrist, longitudinal position of the forearm, the elbow and shoulder, and often the whole body is concerned with carrying out really strong manipulation of objects The hands are used almost entirely to fix the object to the body Examples of this type of grasp are shown by deep-sea fishermen pulling their haul on deck, the act of rolling a cricket pitch, digging, pickaxe work, log splitting, cross-cut sawing, road drilling and plate riveting

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The principles of treatment of this condition are to mobilize the adherent tendons by regular oil massage. Treatment can be started 4 weeks after suture For the first 10 days, oil massage should be given fairly gently twice a day, and this should be combined with active exercise designed to make the fingers extend against gradually increasing resistance. Active resisted wrist extension is also applied. If after the sixth week following injury the tendon adherence is still severe, really vigorous measures must be taken. Oil massage becoming progressively deep and forceful should be used four times a day At the end of each massage, maximum correction should be obtained passively, and a light plaster splint made to fit the deformity is worn between treatment periods In the first week or two of this treatment, the splints may need to be changed twice a day. As the adherence and deformity yield, then the changing of the splint can be altered to once a day, then to once every other day, and then to three times a week It is essential, however, throughout the early weeks of treatment, that the splint be worn at night as well as during the day between treatment periods Throughout this time the patient should be encouraged to use the hand in the treatment sessions to its maximum ability (for a detailed description of the technique for plaster stretch splints *see* Chapter 8)

Severe tendon adhesions usually respond by the beginning of the third week of such treatment and almost complete correction can be expected in most cases within two to three months In our experience any severe degree of tendon adherence of the wrist never becomes corrected by normal use alone Passive stretches and frequent vigorous massage are the only successful measures in overcoming this disability The stretch splints should always be applied to the palm of the hand and volar surface of the forearm, and reach from just below the elbow to well beyond the fingertips Each finger should be lying in a shallow groove on the plaster slab and separated from adjacent ones by cotton-wool. The dorsal splint with elastic tension pulling the flexed fingers out from above must be condemned—this type of splintage tends to cause more deformity rather than to correct it, particularly at the metacarpo-phalangeal joints The palmar type of splinting allows a much steadier and more controlled stretch, and there is no tendency to produce deformity at any other joint Furthermore, there are no slings or adjustments to slip and the splint is lighter and less cumbersome It is, of course, essential to avoid sudden sharp manipulative movements of the fingers or, indeed, of the wrist in correcting this type of deformity Such movement may easily snap a tendon or at the least provoke a severe reaction which will result in further fibrosis We have never known the prolonged application of stretch splinting combined with oil massage fail to correct the severest degrees of tendon adherence at the wrist

Injuries of Tendons in the Palm

Causative factors

The common causes of tendon injuries in the palm are falls on broken bottles, knives, tins and other sharp objects with the hand outstretched People who frequently handle knives in their jobs are liable to injure the structures in the palm Explosions and blast injuries often damage many tendons and digital nerves

Burns may affect the tendons of the hand directly or by scarring of skin and soft tissues

Criteria for primary suture.—Pulvertaft (1950) gave the following criteria for primary suture as opposed to secondary suture of tendons in general. The wound must be reasonably clean, it should not be soiled, or a crush injury. There should be no extensive skin loss, no fracture and no joint injury. Six hours or less is usually the permissible time for suture after injury, and good facilities must be available, including, of course, an experienced surgeon.

The main causes of failure of primary sutures are adhesion between the tendon and soft tissues and bulbous enlargement at the suture site.

It has been reported (Mason and Allen, 1941) that tendons will not take any strain until the third week after suture. These authors went so far as to recommend absolute immobilization for 3 weeks, followed by supervised active movements within the inner range twice daily until the fifth week when all restraint is discarded.

Full function can be restored 6 weeks after injury unless there has been gross damage or complications. Intensive rehabilitation is not necessary: the patient's normal daily activities will bring about full function.

Multiple tendon injuries

In the case of multiple tendon injuries at the wrist, there is a definite liability of adherence of the sublimis tendons to the skin.

To show any degree of adherence, the proximal interphalangeal joint should be slowly extended passively, when puckering of the skin will be seen over the adherent tendons (Fig. 6). When the metacarpo-phalangeal joints are held at



FIG. 6.—*Adherence of flexor tendons to the skin at the wrist*

90 degrees, the proximal interphalangeal joints can be fully extended. As the metacarpo-phalangeal joints are extended, so the proximal interphalangeal joints will flex, indicating the presence of tendon adherence. Whenever there is any degree of sublimis adherence, the effect is always to concentrate flexion on the proximal joint to the exclusion of flexion at the distal interphalangeal joint. For this reason, sublimis is often sacrificed in multiple injuries.

When there is any more than a slight degree of tendon adherence in these multiple tendon injuries, intensive rehabilitation is essential.

ulnar part of the palm at the level of the distal skin crease, both tendons to the middle finger were severed The sublimis was removed and the profundus sutured, intensive rehabilitation commenced 3 weeks after operation At this stage there was no movement at either of the interphalangeal joints, and movements at the metacarpo-phalangeal joints were 110/90 The wound was not completely healed and there was a considerable amount of scarring throughout the ulnar aspect of the palm Three weeks elapsed before the wound healed fully, and consequently stretch splinting was not begun until 2 months after operation Three months after operation there was 10 degrees movement at both interphalangeal joints, and the flexion deformity at the metacarpo-phalangeal joints was reduced to 50 degrees Movements recorded were 130 to 90 degrees Further improvement did not occur in this patient although power of grip and general function were fairly good and he was able to resume his civilian occupation as a draughtsman

The two case histories reported above illustrate the difference in progress that is bound to occur between a simple cutting injury to the flexor tendons in the palm and one involving a gross degree of scarring and soft-tissue damage

Injuries to the Flexor Tendons in the Finger

Injuries of flexor tendons in the finger itself are the most difficult of tendon injuries in the hand to treat

The finger is by far the commonest site of injury of the flexor tendons If the tendon is severed at the base of the finger the tendons will retract deeply into the palm They are found distal to the flexor retinaculum but are prevented from retracting farther by the lumbricals Rank and Wakefield (1953) have pointed out that when division of sublimis occurs at or just distal to the middle crease of the finger the sublimis may retain slight action because the two elements of the sublimis are divided beyond the point of commencement of their linear insertion The sublimis retains the proximal part of this insertion The amount of action will probably depend upon the degree of scarring, thus, a slight contraction at the proximal interphalangeal joint after a cut at the base of the finger should not make the examiner assume that the main tendon has been spared

Causative factors

The common causes of injury in this site are falls on bottles and other glass objects, plunging the hand through window panes, and falls on knives and sharp tins Other frequent causes are severance with razor blades, scissors, saws and bacon slicers, blast injuries (particularly with fireworks), injuries on grindstones, and crushes in machinery and in doors A number of cases have also been seen where the flexor profundus tendon has ruptured during sport—particularly in rugby football where the patient usually sustains rupture of the flexor tendon when endeavouring to remove the trousers of his opponent during a tackle

Pathology

Skoog and Perssom (1954) carried out some interesting experiments on rabbits in order to study the early healing of sutured tendons They found that the scar tissue which forms between the cut ends of a tendon arises from the peritenon and paratenon, whereas the tendon itself does not appear to make any contribution It appeared that the paratenon was the most important structure in healing.

Treatment

Uncomplicated

If both tendons to a finger are involved, it is often worth resecting the sublimis and preserving the profundus, as the action of the profundus alone is adequate for most jobs If the sublimis and profundus adhere to each other the effective agent is the sublimis so that movement is only produced at the proximal joint Primary repair does well in the palm due to the good elasticity in the surrounding tissues The ulna bursa allows gliding and the lumbrical can be wrapped round the suture In the distal part of the palm, however, particularly at the metacarpo-phalangeal joint, the tendon is likely to adhere to the fascial septa of the metacarpo-phalangeal joints and the annular ligaments of the metacarpal heads This is particularly liable to occur with Dupuytren's contracture Tendon injury at this site is, therefore, best treated by a free graft

Uncomplicated primary tendon repairs do not require any elaborate rehabilitation

Complicated

When there has been extensive damage with subsequent adhesions in the palm, intensive treatment is always necessary to mobilize the structures in the palm and to overcome deformity

Provided there is some indication that the tendon is pulling through in the finger and that the general function of the hand, as assessed by functional ability and power of grip, is progressing, one can be sure that the end-result will ultimately be satisfactory It is important, however, to persevere with treatment despite the lack of progress in range of movement

The principles of treatment are exactly the same as for treatment of adherence at the wrist, that is, intensive oil massage and corrective stretch splinting Careful attention is necessary to restore grip to the hand by various types of craftwork and remedial exercises Should a tendon graft be necessary, the after treatment is somewhat different and is the same as that described under grafts for flexor tendon injuries in the finger (*see* page 36)

The following two case histories illustrate the different types of tendon injury to the palm

Case 1—In this case a file penetrated the ulnar aspect of the hand at the level of the mid-palm and severed both tendons to the little finger After 2 months a free graft from the extensor tendon of the middle toe was implanted in the finger, the flexor sheath being excised leaving two slings over the phalanges Gentle active movements were started 10 days after operation and 1 week later intensive rehabilitation commenced On admission to the rehabilitation unit there was no movement at the terminal interphalangeal joint, a flicker of movement at the proximal joint, and movements of 150/110 were recorded at the metacarpo-phalangeal joint Two months of intensive treatment resulted in a full range of movement at the metacarpo-phalangeal joint, 70 degrees (170–100) movement at the proximal interphalangeal joint, and 30 degrees (170–140) movement at the terminal joint, the grip and function were excellent During the first month of treatment little progress at the interphalangeal joints was noticed, it was from the ninth week after operation that rapid progress occurred

Case 2—In this case the patient fell whilst fixing the ventral tank of a Meteor aircraft, lacerating the palm of the left hand The injury caused a jagged scar across the

reasons against tendon suture in the finger. Often the two ends cannot be approximated without tension A certain amount of tendon may have to be sacrificed and the distal end may degenerate with consequent pulp atrophy

It is becoming more and more accepted that a tendon graft is the correct treatment in flexor tendon injuries in the fingers Provided that damage is not extensive, obvious infection is absent, and no bony involvement present, primary tendon grafting is indicated In this series there was one patient in whom a graft was inserted 5 hours after injury

Contra-indications

There are, however, certain contra-indications to tendon grafts If there is severe scarring, the results are unlikely to be good, nor are tendon grafts successful when there are trophic changes from digital nerve injuries Grafting should not be performed when the joints which the tendon is designed to move are stiff Should there be much scarring or stiffness of joints, intensive pre-operative treatment is necessary before a tendon graft is likely to be successful If the sublimis is intact, some surgeons do not perform a tendon graft, but excise the profundus (which otherwise retracts into the palm causing a painful nodule) and arthrodese the terminal joint in 20 degrees of flexion

Technique of tendon grafting

The palmaris longus, the extensor tendons of the toes, or the plantaris tendons are the three tendons used for grafting The need is for a tendon of adequate length and possessing a peritenon to provide a good sliding surround A lateral incision is made in the finger and the tendon excised, the graft is laid in the finger and sutured either with silk or with a Bunnell pull-out wire to the base of the distal phalanx Two pulleys are preserved from the flexor sheath opposite the phalanges as otherwise the tendons will bowstring in the finger A small incision is made in the palm and the tendons pulled through, severed, and removed The graft is then threaded through the pulleys and sutured to the end of the motor tendon in the palm The lumbrical may be wrapped round the suture line to prevent adherence Accurate haemostasis is achieved and the wounds sutured The fingers are bandaged in slightly more flexion than the position of function—the position the hand takes up under anaesthesia It is very important not to overflex the fingers

Pre-operative treatment

This is designed to reduce flexion deformities, restore full passive range and regain as much general function as possible

Passive movements to the interphalangeal and metacarpo-phalangeal joints are given several times a day, avoiding, of course, sudden sharp movements Stretch splinting may be necessary to overcome severe or unduly resistant flexion deformities

A double fingerstall into which the affected and the adjacent normal fingers are bound together is useful, thus, whenever the hand is used the affected finger must come passively into play (Fig 8 *a* and *b*) Craftwork is used to build up the general function and power of the hand

It is very important to establish as good a grip as possible before operation, as grip is lost to a great extent afterwards If the grip has been poor before operation it may take many months to regain the power

When a tendon was cut and enclosed in a thin sheath of stainless steel, no significant regeneration occurred during the first 3 weeks In the case of grafts, the graft was replaced partly by new connective tissue which grew along its entire surface The endotenon played no active part and the peritenon had no specific role, but in its presence the action of the surrounding tissues was less violent resulting in somewhat less firm adherence between the graft and its surroundings Skoog and Perssom point out that tissues with a tendency to lay down connective tissue are unhealthy neighbours for a recently operated tendon because of their liability to lay down organized adherence to the peritenon



FIG 7 —*Flexor tendon graft, finger at operation (From Morley (1956) by courtesy of the author and the editor of British Journal of Plastic Surgery)*

Surgical treatment

Surgical treatment of flexor tendon lesions in the finger (Fig 7) depends on the site of injury If the profundus tendon alone is affected distal to the flexor sublimis insertion, primary suture will frequently be successful If both tendons are affected a free graft is the method of choice, both tendons being completely excised If an attempt is made to repair one or both tendons by suture, adherence of one to the other is inevitable as there is no free space in the flexor sheath to allow for even the slightest degree of scarring The best result will be concentration of tendon action at the proximal interphalangeal joint, but more often than not a finger with limited movement results The tendon graft is sutured to the profundus tendon in the palm where surrounding tissues are more elastic and adhesions are less likely to form

The tendon graft is put in under slight tension so that the interphalangeal joints and metacarpo-phalangeal joint are slightly more flexed than the position of function When the patient starts active rehabilitation the terminal interphalangeal joint is usually held at 175 degrees, the proximal interphalangeal joint at 160–170 degrees, and the metacarpo-phalangeal joint at 150 degrees

Indication

The present surgical opinion on the indications for tendon grafting are that a graft should be used whenever damage occurs within the fibrous tendon sheath Apart from the confined space in which the tendon operates, there are further

free gentle active exercise between the tenth and seventeenth days gives excellent results

In this series most patients started full-time rehabilitation 17 days after operation At this stage the other fingers may be stiff and the injured finger is in some 30 degrees flexion at the proximal interphalangeal joint (held at 150 degrees) and 20 degrees flexion at the terminal interphalangeal joint (held at 160 degrees) There is no movement detectable at either joint, but some 15 to 20 degrees movement at the metacarpo-phalangeal joint (Fig 9 *a* and *b*) The patient usually



(*a*)

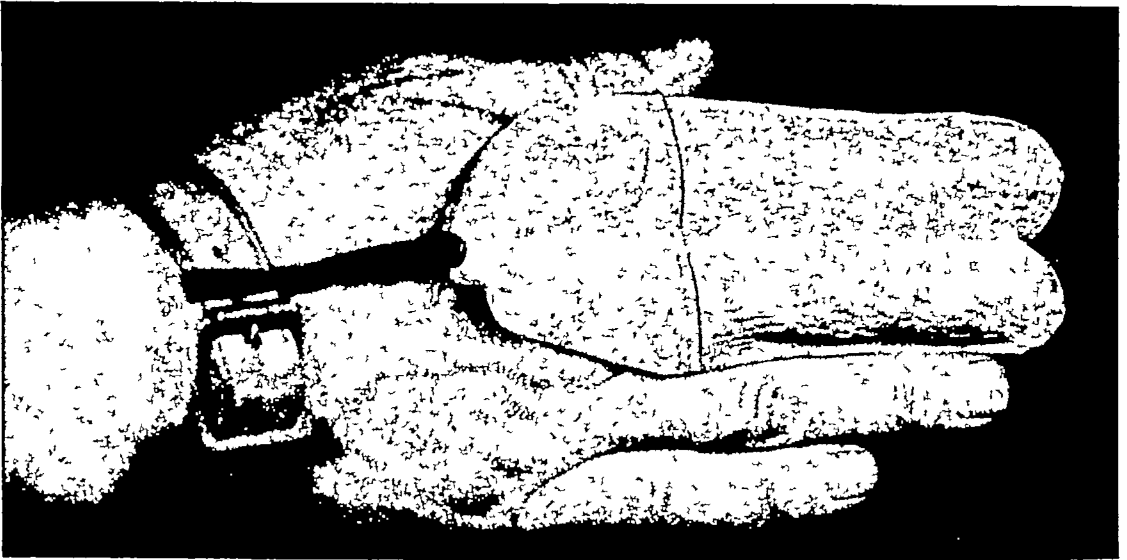


(*b*)

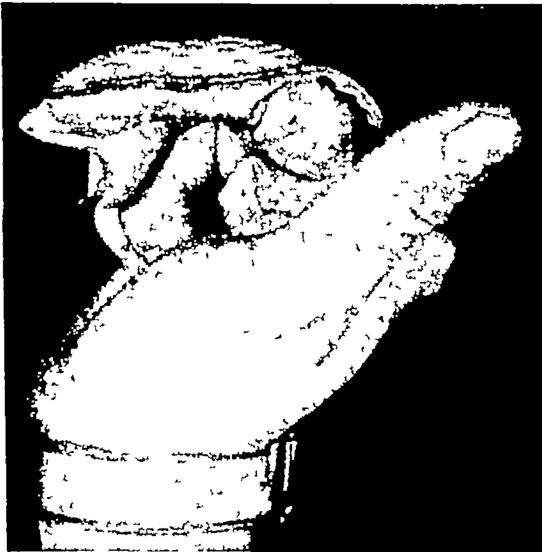
FIG 9 —*Same case as illustrated in Fig 7* (a) *Maximum extension and* (b) *maximum flexion at commencement of rehabilitation 3 weeks after operation*

finds that he cannot use the normal fingers on either side of the one in which the graft has been inserted If more than one finger has been treated there will be very poor function in the hand

In most cases there is some adherence of the palmar scar but none of the donor scar.



(*a*)



(*b*)

FIG 8 *a* and *b* —*Double fingerstall used in rehabilitation following flexor tendon grafts to encourage the use of the grafted finger in the early stages*

Post-operative rehabilitation

General —For the first few days after operation the hand is elevated to prevent oedema The finger is bandaged in the position of function so that it lies in correct relationship to the other fingers while under anaesthesia, that is, with the index finger flexed least and the little finger flexed most If the fingers are overflexed after tendon graft, the results are likely to be disastrous because it may prove impossible to overcome the flexion deformity The wrist is flexed Plaster and splints are not necessary in the immediate post-operative treatment

Surgeons differ in their opinions as to when active exercise should start after tendon graft Bunnell (1956) advocates a very early start and allows movement in the first day or so Most surgeons, however, do not allow active movement for 7-10 days There is no evidence to suggest that very early mobilization results in any quicker or better return of function The results in this series suggest that

there is no digital nerve injury Hence, all patients must be strongly reminded of the precautions to be taken against excess heat or cold to the hand and they should wear gloves in cold weather The number of times the exercises are repeated is gradually increased for the first 2 weeks At the beginning of the fifth week after grafting, resistance exercises are started Continual encouragement is required from the physiotherapist to exhort the patient to work increasingly

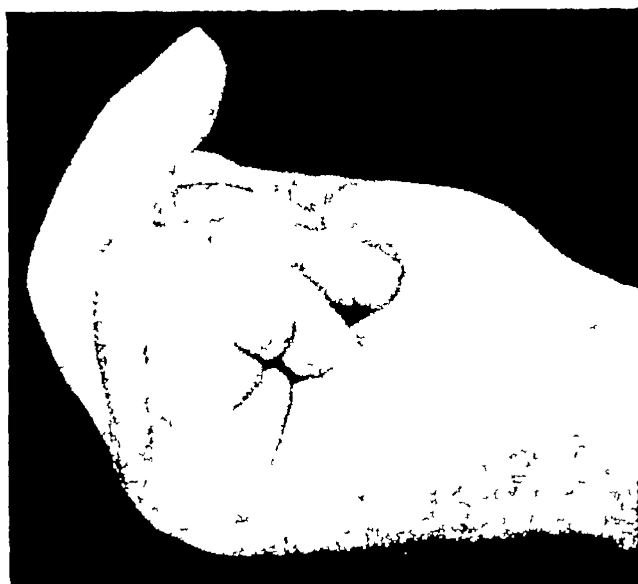
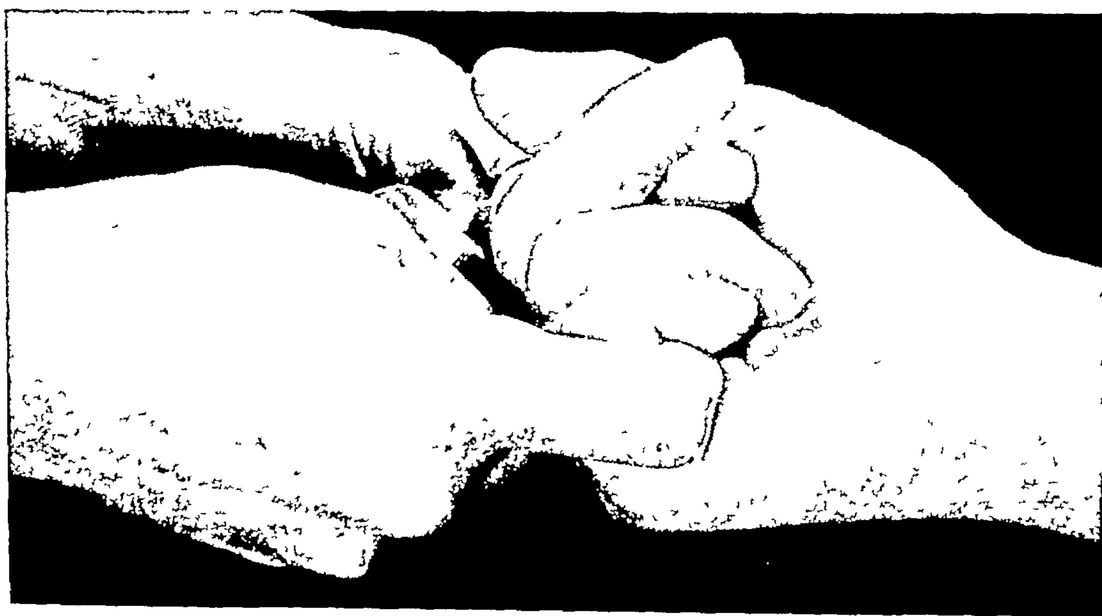


FIG 10 *a* and *b* —*Applying resistance to proximal interphalangeal joints of adjacent fingers when exercising grafted finger*

(*a*)



(*b*)

harder against her resistance When the patient is flexing the grafted finger, resistance is given to the other interphalangeal joints in order to bring the grafted finger into action to the maximum possible extent When this is done it will be seen that more movement occurs in the affected finger on giving resistance to the others than without (Fig 10 *a* and *b*) Again, the patient's attention should be

Physiotherapy in uncomplicated cases.—The finger is cleaned with cotton-wool and warm saline solution, and then dried. If the wound is healed a wax bath is given; if not, warm saline solution soaks are used and the patient is asked to move the fingers as much as possible in the saline bath. After drying, the whole hand is given a light warm olive-oil massage to improve the general condition of the skin, which tends to be dry and scaly. Oil is preferable to cream as it is easier to rub in. Circular light frictions are given to the palmar scar and a very light mobilizing massage given to the finger scar. This should be done in elevation if there is any oedema of the finger.

The unaffected fingers are then actively exercised throughout their full range of active movement and each joint is exercised against the physiotherapist's resistance. These general exercises for the unaffected fingers are a very important preliminary to the treatment of the grafted finger because associated movements are encouraged in order to help the affected finger to move with the normal ones.

Attention is now turned to the injured finger. The physiotherapist shows the patient the movements required by using the corresponding finger of the normal hand. Each phalanx is supported and the patient is asked to flex the terminal and then the proximal interphalangeal joint. These movements are then repeated with the injured finger. The metacarpo-phalangeal joint should be slightly flexed for this exercise. If no movement is seen at either interphalangeal joint, the amount of metacarpo-phalangeal flexion is progressively increased until movement occurs. If no movement is seen and if the patient has no sensation of the tendon pulling through, his attention should be focused on the tendon action at the wrist joint. If the patient can see and feel the tendon working at the wrist he will have a better idea of this action throughout the finger. Again, this should be done on the normal side first. If the finger is very stiff, as is not uncommon in the early stages, it should be made to work in association with the other fingers; that is, the grafted index finger to work with the thumb, the middle finger with the index and ring fingers, the ring finger with the little finger.

No passive movements should be applied to the grafted finger for 6 weeks after operation for fear of damaging the graft. When little or no movement is present at the interphalangeal joint, the patient will attempt to trick by extending the joint and then relaxing it, thus giving a spurious idea of flexion. To prevent this the finger should be extended first against resistance and then flexed, working against the light resistance of the physiotherapist's finger. Each joint should be flexed against light resistance in turn. When exercising metacarpo-phalangeal flexion the wrists should be held palmar surface down on the table, supported by the physiotherapist's hand, and the patient asked to bend the metacarpo-phalangeal joints whilst keeping the interphalangeal joints straight, this being the lumbrical action. The exercise session is ended by the patient gripping the physiotherapist's hand, both being supported on the table. The patient should again concentrate on the tendon action at the wrist.

If the finger is very sore at this early stage, the gripping exercise is not possible; instead, the patient is asked to blow a piece of cotton-wool along the table by compressing a soft rubber syringe with his injured hand. At the beginning, each exercise should be repeated three times, the whole session lasting 30 minutes. Two sessions a day are given.

For a long time the affected finger is colder than the rest of the hand, even if

should, therefore, be given to building up power and movement in the proximal interphalangeal joint

Physiotherapy in complicated cases—If there is any degree of flexion deformity, resistive exercise is started for the extensors of the fingers 4–5 weeks after operation At 5–6 weeks after operation, stretches should be given to the deformity 4–6 times a day The joint proximal to the deformity is supported and a pull exerted on the affected joint only, this should be a very slow and steady pull and at the maximum correction should be held for 2–3 minutes

When the fifth finger is concerned it will be found easier to treat it in the following manner The fingers are allowed to hang over the edge of a table and the proximal phalanx is supported with the fingers, with the metacarpo-phalangeal joint in slight flexion It will be found that the stretch to the distal joint of the fifth finger is much more easily made in this position To overcome the flexion deformity, the patient should be asked to flex the metacarpo-phalangeal joints while the interphalangeal joints are extended The production of this intrinsic action results in the affected interphalangeal joint automatically going into its maximum extension

Before the stretching, oil massage to the scarring is given Alternate flexion and extension with resistance helps to reduce the flexion deformity When maximum correction has been obtained by this means, a plaster splint is applied to the finger in this position and worn between treatment periods

Vigorous work to the tendon should not be allowed until the eighth week after grafting, by which time there is no danger of damaging the tendon provided that the proximal joints are always carefully supported during stretch and movements, the latter are never allowed to be sharp or sudden

In these cases of flexion deformity, the palmar scar is almost always adherent so that deep frictions both transverse and longitudinal are applied directly to the scar

Occupational therapy—In the uncomplicated case, wounds are healed and therefore there is no special need to guard against friction during craft work If, however, the wound is not fully closed and there are stitch abscesses or scabs, the finger should be covered with a muslin fingerstall In all cases a double fingerstall is provided into which the grafted finger and that adjacent to it both fit so that flexion of the normal finger will bring down the grafted finger with it This re-creates the pattern of movement and the patient recovers the feeling of using the finger (Fig 8 *a* and *b*)

Occupational therapy begins at the third week after grafting and, from the third to the fifth week, free activity is encouraged without attention specifically to movement at the interphalangeal joints Basket work is ideal for the thumb, the index or middle fingers For the ring and little fingers, any craft involving the use of a handle bent at 125 degrees is appropriate, a loom, for example, can have an adaptation handle bent thus to give ulnar deviation because in this manner the fingers are forced to flex The position of the adaptation handle is important It can, for example, be arranged on a drill so that holes can be drilled in metal or wood

Craft work is given for 2 hours a day, 1 hour in the morning and 1 hour in the afternoon It is best given after physiotherapy and is followed by remedial

concentrated on the feeling of the tendon acting both in the finger and at the wrist

By the sixth week after starting intensive rehabilitation, isometric resistance work can begin with the patient holding each joint against the physiotherapist's resistance at the extreme of movement By this stage really strong resistance can be given The patient should carry with him a tennis ball and grip it as often as possible Patients who are not improving in power satisfactorily are given spring hand grips to work against at frequent intervals To encourage the grafted tendon to work really hard, the metacarpo-phalangeal joints are supported in extension and prevented from flexing The patient is then encouraged to bend the interphalangeal joints whilst resistance is given to the unaffected ones This manoeuvre prevents the lumbricals from acting and forces the flexor graft to work really hard Both big and small grips are encouraged, the patient first gripping the physiotherapist's hand, then 3 fingers, then 2 and then finally 1 finger

All the hand muscles should be re-educated at each treatment session, and the importance of the fact that the hand works as a unit and not as isolated muscles should never be forgotten In particular, the intrinsic muscles and the finger extensors must receive detailed attention Abduction and adduction of the fingers against resistance, and flexion of the metacarpo-phalangeal joints with interphalangeal joints extended, are encouraged Invariably the extensors will be found to be weak also, and it is at this stage that specific re-education of the finger extensors is started The interphalangeal joints are extended against increasing resistance, the wrist is fixed and the physiotherapist places the palm of her hand over the dorsal surface of the finger and asks the patient to hold his fingers extended against her palm The physiotherapist can increase the resistance which she puts on the fingers at each session

Another useful exercise is to ask the patient to flex the metacarpo-phalangeal joints, hold the interphalangeal joints in flexion, and with the wrist fixed, extend the metacarpo-phalangeal joints only, against resistance In all these exercises the movements required should be performed passively by the physiotherapist 3–4 times, the exercise can then be carried out by the patient with assistance, and then finally on his own

There are a number of diversional exercises that are most useful in the re-education of tendon grafts A thimble is held between the thumb and index web by the patient and he tries to bring his affected finger into the thimble and out again If there is not enough flexion in the finger, the thimble is held between the thumb and one finger The patient is asked to roll two marbles around each other in the palm of his hand using his fingers and thumb The finger can be exercised against spring resistance using a strap and spring around the appropriate phalanx with a 5 lb spring Picking up beans of different sizes and shapes is a useful exercise, and gripping a handful of lentils and allowing them to drop one at a time out of the hypothenar part of the hand Games can be devised involving flicking marbles to exercise the extensors A crepe bandage is unrolled for 18 inches, the patient places his palm down on top of it and, by grasping with his fingers, unrolls as much as he can grasp at one pull and then extends his hand to grasp the next length In the exercise the whole bandage is unrolled Later, a stiff rubber bandage can be used to provide resistance Throughout this regime it must be remembered that the greatest disability is lack of movement in the proximal interphalangeal joint. Movement in the terminal interphalangeal joint matters less, and priority

important to record this Accurate measurements of joint range are essential, for it is only by this means that deterioration in the condition can be assessed The examiner should be aware of the ability of the extensor tendon to trick the flexor action by its relaxation after contraction If the joint is palpated carefully, trick action can always be detected because the opposite movement to that desired is always produced first

The active range should be measured with the metacarpo-phalangeal joints extended and flexed

(3) The distance from the tip of the finger to the distal palmar crease If there is only a little flexion at the joints, this is not easy to perform and the best measurement is then the perpendicular from the tip of the finger to the palm of the hand

(4) Power of grip, using a small dynamometer

(5) Active extension should be looked for and recorded at both interphalangeal and metacarpo-phalangeal joints

In the thumb it is important to test the range of function in both flexion and extension of the carpo-metacarpal joint, in full extension the interphalangeal joint may go into flexion and it is important to record this

An important function of the flexor pollicis longus is the power of pinch between the thumb and fingers, and this should always be tested by asking the patient to pinch between the thumb and index finger and assessing the amount of resistance to this pinch

Assessment of results—There is a certain amount of controversy about the assessment of good and bad results Many reports of series of flexor grafts do not specify exactly what is meant by good and bad results Flynn's (1953) good result is 90 degrees movement at each interphalangeal joint, and the finger within ½ inch of the distal crease in flexion A fair result is 45 degrees movement at each interphalangeal joint and with the finger within 1½ inches of the distal crease in flexion, while a poor result is one in which there is less than 45 degrees movement at the interphalangeal joints and more than 1½ inches from the distal crease in flexion Morley (1956), on the other hand, suggests, as an excellent result, full extension, flexion to within ¼ inch of the mid-palmar crease, good, full extension, flexion to within 1 inch of the mid-palmar crease, fair, full extension, flexion to within 2 inches of the mid-palmar crease, and poor, less than that defined for a fair result

So much of the success in a tendon graft depends on what the patient is going to do with his hands, but it would seem wise to record all the information available so that long-term assessment can be made In this series Morley's criteria are used, in addition the range has been recorded in the equivalent joints of the other hand

Factors affecting the results of finger grafting—An analysis of over 100 tendon grafts treated at our Centre showed that they fell into the following three main groups

Group 1 Those that made a rapid recovery and achieved 50 degrees at the proximal interphalangeal joint and 45 degrees or more at the distal joint by the end of the third month after operation In this group there were no complications either during or after operation, and the pre-operative condition of the finger was good, furthermore, the patient was keen to get the hand better as quickly as possible

Group 2 In this group, fairly good function of the hand was regained, but less

exercise in the gymnasium. The chief aim at this stage is to increase movement at the metacarpo-phalangeal joint and to promote general hand function

At the fifth week harder work is allowed and carpentry is ideal The principles of occupational therapy for tendon work is that it should involve grasping The use of a chisel, a file, or a small screwdriver is the best method of promoting tendon function in the thumb, the index and middle fingers For the ring and little fingers, light metal work is best and may include making lamps, candlesticks, and hinges for lively splints for disabled patients Piano playing may be encouraged to develop co-ordination and power It is important not to prescribe too powerful work, otherwise the patient will not use the affected finger

The harder work at this stage of recovery is designed primarily to build up general power and function of the hand rather than to regain range of movement in the interphalangeal joints This, after all, is not a function of occupational therapy, and increase in range, particularly of small joints, is much better achieved by individual exercise in the physiotherapy department

Leather work is best avoided in tendon injuries, for patients are very inclined not to use stiff fingers in this craft

If the patient tends not to use his fingers, particularly in grafts of the ring and little fingers, punching leather is an excellent craft as it is impossible to perform this without using the ring and little fingers strongly

Where women are concerned, pottery—particularly coil pottery—and modelling are appropriate crafts, though pottery should not be prescribed before the fifth week due to it being a wet and somewhat dirty craft Needlework is too light a craft and should not be used in tendon re-education At this stage, games are introduced A general game for hand function which is excellent for tendons is " blow football "

At the eighth week, heavy work of any type can be started, for example, all types of carpentry, cross-cut sawing, cementing, stool seating and big loom rug making with springs attached for power

As in all types of occupational therapy, the emphasis should always be on getting the patient really interested in the craft, and to achieve a high standard of workmanship

The basic principles of occupational therapy in tendon lesions are, first, to encourage the patient by every means to use the affected finger as an integral part of the hand, and, secondly, the development of muscle power

Results

Measurements —When examining the hand in the clinic, the following measurements should be made and recorded

(1) Range of passive movement at each affected joint
(2) Range of active movement at each joint

When testing the range of active movement, the joint should be stabilized and the patient asked to bend the joint as much as possible Resistance is given to the equivalent joints of the normal fingers for 3 or 4 pulls and the joint range measured with a small goniometer The range should be recorded as extension to flexion, that is, 180 to 100 degrees, *not* 80 degrees of movement, for there is almost always a flexion deformity in the early stages after tendon grafts, and it is

important to record this Accurate measurements of joint range are essential, for it is only by this means that deterioration in the condition can be assessed The examiner should be aware of the ability of the extensor tendon to trick the flexor action by its relaxation after contraction If the joint is palpated carefully, trick action can always be detected because the opposite movement to that desired is always produced first

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Group 2 In this group, fairly good function of the hand was regained, but less

movement at the joints was obtained The average range of movement on discharge was 30 degrees at the proximal joint and 25 degrees at the distal joint

Group 3 In this group there was a very poor range of movement at the interphalangeal joints, although power of grip and general function were usually fairly good

On referring to the operative findings it was found in the second and third groups that there were definite complicating factors In Group 2, the commonest complication was adherence of the scar, either in the palm or finger, or both Other complicating factors included a poor pre-operative state of the finger in that the joints were stiff and the circulation poor There was destruction of the lumbrical muscles in some cases Moderate scarring was present due to the injuries being ruptures rather than clean cuts, and injury of digital nerves as well as tendons at the time of injury

All the severe complications were found in Group 3 These included gross adherence, infection, scar contraction, destruction of the fibrous flexor sheath, haematoma formation, gross oedema, crush injuries, excessive scarring and fibrosis, or a long history of previous operations and even previous grafts

The general progress of each group was quite distinct

In Group 1 (the uncomplicated cases) the most movement occurred in the first 8 weeks after operation There was usually a flicker of movement of both interphalangeal joints by the twenty-seventh day after operation By the seventh week after operation there was some 50 degrees movement in the proximal interphalangeal joint and 35 degrees or more at the terminal interphalangeal joint The finger flexed down to the palm well, and the power of grip was excellent, usually being up to only 2 lb less than the normal hand These patients were fit to return to work between the eighth and twelfth weeks, depending on their jobs, and when reviewed at 6 or 12 months later, still showed signs of increasing movement in the joints and improvement of function By 1 year almost all patients had a full range of movement at all joints and could make a complete fist

In Group 2 movement started about the same time after operation as in the above cases but by the sixth week after operation there was never more than 30 degrees movement in the proximal joint and 10–15 degrees at the terminal joint From the sixth to the ninth week very little progress was noted From the tenth week onwards gradual progress continued, however, and most patients in this group were fit to return to work between 14 and 16 weeks after operation A gradual increase in function was noted on subsequent review, even 1 year after operation when there was an average of 25 degrees more movement in the interphalangeal joints

In Group 3 no movement at either interphalangeal joint was seen for the first 6 weeks after operation None of the patients in this group ever achieved more than 30 degrees movement at the proximal interphalangeal joint or more than 10 degrees movement at the terminal interphalangeal joint and, of course, they were not able to bring the finger down into the palm Despite this, general function was often good and for this reason intensive treatment was justified

On review 1 year after operation a few patients showed an increase of 15 degrees or so in range over and above their range on discharge, but most showed none One or two patients whose work did not involve much use of the hand showed a slight decrease in range

These patients require a much longer period under treatment than either of the first two groups because there is so much more to be done A grossly scarred palm, for example, requires intensive oil massage several times a day Many of the patients, moreover, need stretching and plaster splints Those patients with gross oedema in the early stages must have their hand in elevation until the oedema has subsided, so that not only are they unable to start intensive work earlier, but they inevitably develop considerable fibrosis, particularly if the oedema is disregarded

An analysis of the time injury to the time of operation showed that there was no relation between delayed treatment and the incidence of complications The period between injury and treatment in the above group of patients ranged from 17 days to 7 years

The pre-operative condition of the finger is important and a first-class result was never obtained in a finger that had not a full range of passive movement and that had more than minimal scarring before operation

In summary, if no movement is observed in either interphalangeal joint by the sixth week after operation it can be assumed that the range of movement ultimately achieved will be poor, and once the patient's grip has been re-developed and his function is adequate for his job, no further treatment should be given If improvement is maintained up to the fifth week after operation but progress then seems to stop, one should not despair but continue encouraging the patient to work hard, as by the ninth week progress should recommence This delay in progress is common in patients with minor complications Although no increase in range of joint movement is seen during this period, power and function continue to improve If by the sixth week there is 50 degrees movement or more at the proximal interphalangeal joint and 30 degrees movement or more at the terminal interphalangeal joint, a first-class result can be expected

In none of the cases that had a persistent sensory loss due to a digital nerve lesion was an excellent result obtained It seems that this is a disability of considerable importance Possibly the concomitant vascular damage is of significance

There was no difference in the results in various fingers It might be expected that the little finger would not progress as the index or middle fingers, but this is not so, results are the same for each finger, in the absence of complications When comparing end-results in patients who have had full-time rehabilitation after grafting, with those who have not, there is no doubt at all that the rehabilitated patients have far better movements and function, and one cannot emphasize too strongly the desirability of post-operative rehabilitation for a period of 8–10 weeks

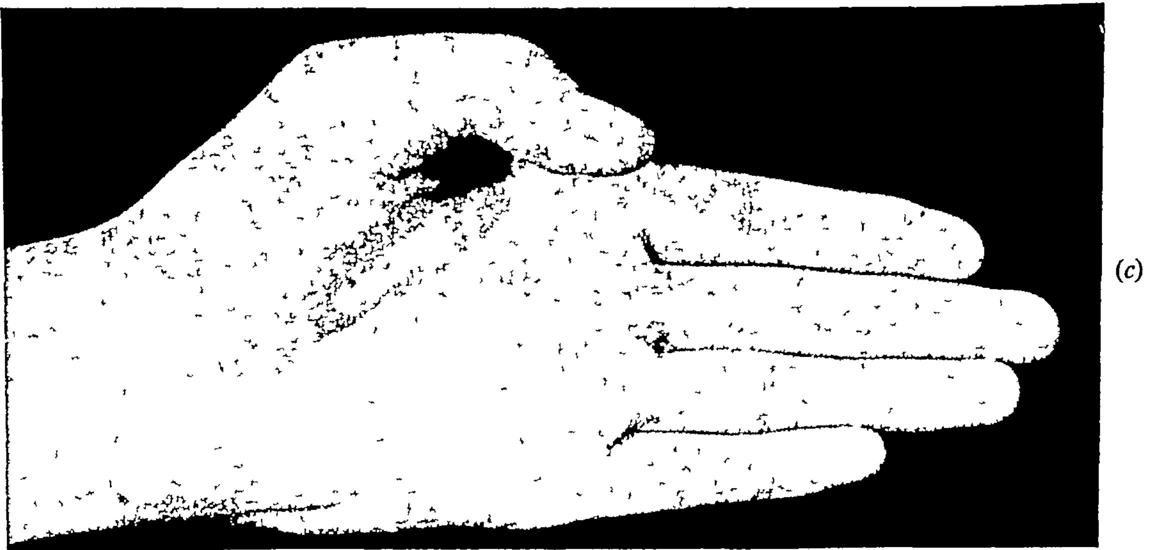
Results of grafts to the thumb —Grafts to the flexor pollicis longus do extremely well The uncomplicated case achieves 40 degrees movement at the interphalangeal joint between the fourth and sixth weeks and 60 degrees movement or more by the ninth week after operation (Fig 11 *a*, *b* and *c*) By 6 months a full range of movement is obtained Again, the poor results were in those patients with much scarring and thickening in the thumb, or where there was digital nerve involvement as well.



(*a*)



(*b*)



(*c*)

FIG 11 —*Result of graft to flexor pollicis longus 12 weeks after operation* (a) *Opposition to minimus* (b) *Flexion, in this position with a poorly functioning graft the interphalangeal joint falls easily into extension* (c) *Flexion with carpo-metacarpal joint extended*

If there has been only a small loss of tendon in injuries to the flexor pollicis longus, the tendon origin can be slid down the muscle belly in the forearm, thus obviating the necessity for grafting This, of course, is only applicable when the tendon is severed reasonably near its insertion

Complications

Nature and frequency.—The following are the commonest causes of poor results from a tendon graft, producing stiffness and flexion contractures of the finger.

(1) *Excessive scarring* in the finger is very common, and is often accompanied by scarring in the palm The degree of scarring is related to the amount of damage at the original injury, to haemorrhage at operation, and to failure of inadequate surgical repair previously, but there remains a small group of patients in whom conditions are ideal and yet excess scarring occurs. It seems that there are patients in whom scar tissue grows exuberantly and these cases are liable to an imperfect result

(2) *Digital nerve injury accompanying the tendon lesion.* In all cases in our series where digital nerve damage had occurred and sensation did not return, the results were never perfect In some, an atrophic finger pulp was a feature In all, the range of movement was never full even months after operation, though eventually patients with no other complications did achieve good function some 12–18 months later When successfully sutured at the time of tendon grafting, the results were in all cases excellent provided no other complications existed

(3) *Stiffness of the finger before operation* If a graft was carried out when, through one reason or another, the finger had not full passive range, or the power of grip was much reduced, results were never good It cannot be too strongly stressed that patients should always be given pre-operative treatment to obtain a full range of passive movement, good power of grip, and good general hand function before grafting is attempted Sometimes it is not possible to achieve these ideals and in these circumstances it should be appreciated from the outset that a perfect result is impossible

(4) *Any general disease may interfere with the rehabilitation,* particular examples are where excessive haemorrhage occurs from blood disorders or vascular disease, or where the evidence of general disease is apparent locally in the hand and interferes with function

(5) *Grafts too long or too short* If the graft is too short, or is inserted under too much tension, the fingers will be hyperflexed Provided there has been a minimal range of passive movement and minimal scarring before operation and there are no other complications, this usually stretches out to result in good function with the routine treatment described Resistant cases need the slow sustained stretch with serial plaster splints as previously described If the graft is too long extra hard work is required to take up the slack In such cases progress is slower than usual, but eventually a good result is obtained provided there are no other complications

(6) *Lack of co-operation from the patient.* If the patient is not interested in his rehabilitation, tendon grafts will almost certainly be a failure, hence it is always very important that the patient understands throughout all stages of surgery and

rehabilitation what is being done and what is his part in the process. Some patients do not make the progress expected of them They may be frightened of the ache produced in the early stages after operation when they start active exercise, and it must be explained to them that a little discomfort is inevitable Very few patients took no interest at all in their rehabilitation, but there were a number in whom constant explanation and reassurance throughout were necessary, indeed, this applied to patients with all types of hand disability, particularly in those where treatment is continued over many weeks or months

All members of the team must strongly encourage the patient to keep at his treatment and do everything in their power to sustain his interest

It is, of course, essential to explain to the patient what is being done, how long it is likely to be before he obtains good function and is able to go back to work, and why he is having the various treatments If the patient shows consistent lack of interest in his condition and unwillingness to exert himself in the department, it is a waste of time to continue treatment

(7) *An occasional cause of a bad result is a poorly planned surgical incision*, but this is, fortunately, with the increasing understanding of hand surgery, becoming extremely rare Perhaps the most serious mishap in hand surgery is to make a long incision down the middle of the volar surface of the finger

(8) *Breaking of the graft* This may happen if over-enthusiastic rehabilitation is started too early, if too much strain is put on the tendon within the first 8 weeks or if the graft itself is too thin

Conservative treatment of complications —Conservative treatment should always be tried first for every adherent tendon

As the result will not be judged until 8 weeks have elapsed since operation, vigorous treatment can be undertaken without fear of damage to the grafts This includes oil massage four to six times a day, serial plaster splints after full passive correction, and wearing of night splints, combined with really hard work for the hand in the occupational therapy department

Where there has been so much damage to the hand as to produce a poor result, most patients will not benefit from further surgery as this is more likely to make the hand worse Except in the most severe flexion deformities when, for example, the little finger is closed right up into the palm, reasonable function returns with this line of treatment

Surgical treatment of complications —When tenolysis is undertaken, all adhesions are severed, the tendon being fully exposed so as to ensure that its action is normal Glide material, such as fascia taken from the forearm, is sometimes inserted and vigorous rehabilitation commences immediately after operation

Regrafting can be carried out provided that the finger is in good condition.

Grafts were found to have stretched in 2 cases some 6 weeks after operation. In both these cases stretch occurred whilst performing normal active hand exercise, so there was no question of over-enthusiastic treatment The pathologist was unable to suggest a reason for this occurrence Both patients were regrafted with excellent results This phenomenon has been reported in the literature when the suggestion has been made that the stretch is due to free movement too early This, of course, was not the operative factor in the 2 cases mentioned above.

The following are examples of tendon grafts in patients where conditions were good

Case 1 Laceration of the right middle finger on broken glass on 24 11 54 Operation was carried out 4 months later The flexor sublimis was excised and a free graft using the palmaris longus was performed The patient came to the rehabilitation centre 3 weeks later, at which time movement at the terminal interphalangeal joint was 180–170 and 180–150 at the proximal interphalangeal joint Ten days later there was 35 degrees movement at the terminal interphalangeal joint and 45 degrees at the proximal interphalangeal joint Seven days later (38 days after operation) there was 45 degrees movement at the terminal interphalangeal joint and 55 degrees at the proximal interphalangeal joint On discharge 5 weeks later (73 days after operation) movement at the terminal interphalangeal joint was 180–100, at the proximal interphalangeal joint 180–100, the metacarpo-phalangeal joint 180–85, and the finger flexed to within ¾ inch of the mid-palmar crease The patient returned to full duty as a fireman On review 4 months later the movements were full and hand function normal

Case 2 This patient sustained a cut on the left index finger with a tin but did not come to operation for 7 months A palmaris graft was inserted after excision of the sublimis and profundus At operation much adherence was noted It was expected that this patient would not do particularly well in view of the operative findings and the delay from the time of injury to surgical treatment

On admission to the rehabilitation centre 3 weeks after operation there was 5 degrees movement at the terminal interphalangeal joint (170–165) and 10 degrees movement at the proximal interphalangeal joint (150–140) No further improvement was observed for 3 weeks, after which time the patient began to make steady progress though he found much difficulty in using the finger in co-ordination with the others

Eventually (3 months after operation), the patient was discharged to duty as an armament mechanic with 75 degrees movement at the proximal joint, 20 degrees movement at the terminal joint, and excellent power

This case shows the value of intensive rehabilitation and the good result that can be obtained despite the presence of much scarring and the long pre-operative delay

Case 3 Rupture of the flexor tendons of the left ring finger occurred in this patient whilst playing rugger A palmaris graft was performed one month later It was noted at operation that both tendons were firmly adherent in the palm Both tendons were excised The patient came to the rehabilitation centre 22 days later when it was observed that he had 20 degrees movement in the terminal interphalangeal joint, 30 degrees at the proximal interphalangeal joint, and the grip was half that of normal A fortnight later the tendon snapped whilst the patient was doing a free exercise, and 2 weeks later a new graft was inserted using the second toe extensor Rehabilitation recommenced 1 month later when there was 15 degrees movement at the terminal interphalangeal joint (180–165) and 10 degrees at the proximal interphalangeal joint (170–160) After treatment for 1 month, that is, 8 weeks after the second operation, movement at the terminal interphalangeal joint was 180–120, at the proximal interphalangeal joint 180–85, and at the metacarpo-phalangeal joint 180–90 The finger came to within ¾ inch of the mid-palmar crease The patient returned to work as a mechanic at this stage, with excellent hand function (Fig 12)

Case 4 Broken glass was responsible for a cut on the right ring finger in this case, and 12 days later a palmaris graft was performed, the sublimis tendon being left intact as it was not damaged in any way Rehabilitation commenced 3 weeks later when there was 15 degrees movement at the terminal interphalangeal joint and 20 degrees at the proximal interphalangeal joint Two months after commencing rehabilitation the patient returned to full duty as a physical training instructor with 180–120 at the



FIG 12—*Case 3 Maximum flexion of ring finger on discharge, 7 weeks after regrafting*

terminal interphalangeal joint and 170–90 at the proximal interphalangeal joint, grip being within 2 lb of the normal side

Case 5 This patient sustained an avulsion of both flexor tendons of the right little finger when a firework exploded in his hand Apart from the tendon injury there was tissue damage and subsequent scarring Two months later a tendon graft was performed using a toe extensor, both sublimis and profundus being excised Rehabilitation was commenced 3 weeks later After 3 months' treatment movement was 180–125 at the terminal interphalangeal joint and 180–120 at the proximal interphalangeal joint In flexion the finger lacked ¾ inch from the mid-palmar crease and the grip was 2 lb less than the normal side This case illustrates that a good result is possible even in the presence of surrounding soft-tissue damage from a blast injury

Case 6 This patient fell against a door, forcing his right hand through a glass window pane, and as a result sustaining division of both flexor tendons of the little and ring fingers of the right hand Three weeks later the patient came to the rehabilitation centre for pre-operative mobilization of the fingers and improvement of general function After 2 weeks' intensive treatment, full movements were obtained passively but it was noted that the circulation was not good in either finger At operation the digital nerves were sutured and a palmaris longus graft was inserted in the right ring finger At operation the flexor sheath was found to be severely damaged and there was much adherence

Rehabilitation was started 3 weeks after operation The terminal interphalangeal joint was held at 135 degrees in 45 degrees of fixed flexion The proximal interphalangeal joint showed 3 degrees flexion only from the position it was held in at 135 degrees There was 90 degrees movement in the metacarpo-phalangeal joint

After 4 months' intensive treatment, including serial stretches, the result was disappointing There was only 10 degrees movement at the terminal interphalangeal joint from 150 degrees and 15 degrees flexion at the proximal interphalangeal joint from 150 degrees The finger could, however, be flexed to within 1 inch of the mid-palmar crease and the grip was very powerful The patient was able to return to his job as a wireless operator, but on review 6 months later it was found that movement at the proximal interphalangeal joint had not improved

This case illustrates that despite correct surgery and intensive after-treatment, a good result cannot be obtained if too many complications are present In this case the circulation was poor, the digital nerve had been cut and there was much scarring

Case 7 The blade of a knife had severed the flexor tendons of the left index and middle fingers and the digital nerves of the index fingers in this case Tendon grafts were performed 21 days after injury and the patient was transferred to the rehabilitation unit 35 days later

After 8 weeks of intensive treatment 35 degrees flexion of the terminal phalanx of the index finger and 50 degrees of the proximal phalanx was achieved, but only 5 degrees at the interphalangeal joints of the middle finger

As there were no other complications a tenolysis was carried out and within 8 days of operation movement at the proximal joint was 50 degrees and at the terminal joint 15 degrees, 31 days after tenolysis the patient was discharged to work with 50 degrees movement at the proximal interphalangeal joint and 45 degrees at the terminal joint Function was excellent

Case 8 This patient sustained a tear of the flexor tendons of the right index finger and an open wound which became infected One year later the tendons were seen at operation to be adherent and there was much capsular thickening Sublimis was excised, a graft inserted, the lateral ligaments resected and the capsule thinned On admission to the rehabilitation centre 17 days after operation the terminal interphalangeal joint was held at 150 degrees and the proximal interphalangeal joint at 135 degrees Nine days later there was 5 degrees movement at the terminal interphalangeal joint and 20 degrees at the proximal interphalangeal joint

Four weeks later the proximal interphalangeal joint began to go into hyperextension (Fig 13 *a*) and a plaster splint was made which the patient wore when not actively engaged in treatment (Fig 13 *b*) The hyperextension persisted, although it diminished by treatment, and prevented proper initiation of flexion by the graft as so much " slack " had to be taken up before flexion could start (Fig 13 *c*) Grip, however, was good, and the patient returned to duty after 3 months' rehabilitation In another case of hyperextension of the proximal interphalangeal joint Mr R Furlong opened the joint and scarified the flexor aspect of it This prevented the joint from hyperextending and an excellent result was obtained

EXTENSOR TENDONS

Although results of treatment for extensor tendon injuries on the dorsum of the hand are normally excellent, lesions of the extensor tendons over the phalanges can be as difficult as flexor tendons in the fingers, a fact which is not generally appreciated There is a tendency to regard the rehabilitation of extensor tendon injuries as straightforward and function to be in any case less important The difficulties of treating lesions of the extensor expansion must not be underestimated

There are certain important differences between extensor and flexor tendons Rank and Wakefield (1953) have drawn attention to these. They point out that accurate suture of extensor tendons is more difficult owing to their thinness There is a lack of soft-tissue cover and the bones and joints are much closer, with the result that concurrent injury to these structures is more common

The distinction between an extensor tendon and the posterior capsule of the joint does not exist, hence a divided tendon at this site means a repair over an open joint

Lesions at the proximal interphalangeal joint usually involve the central tendon As the lateral tendons may not be involved loss of function may not occur for

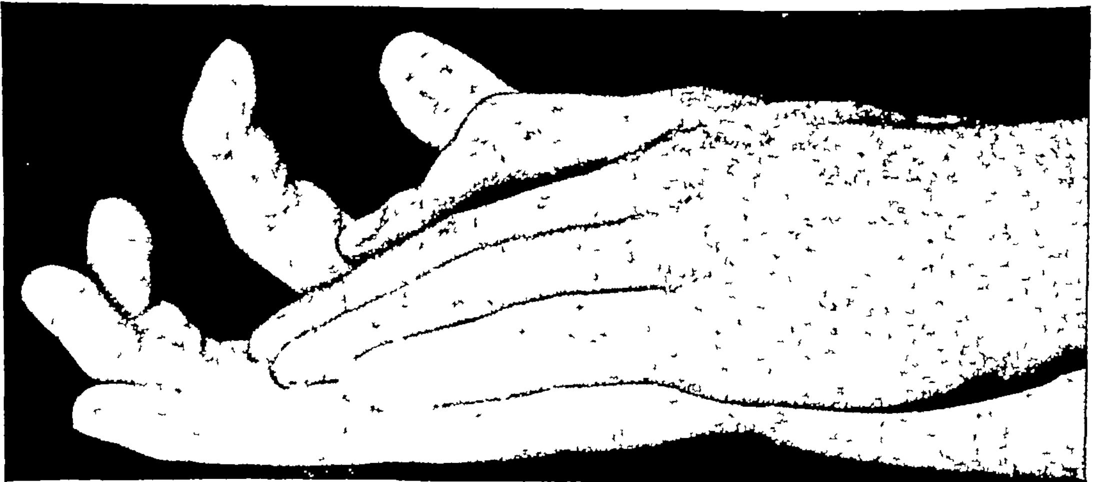


(*a*)



(*b*)

FIG 13 —(a) *Hyperextension of proximal interphalangeal joint of the index finger* (b) *Plaster splint used in treatment* (c) *Maximal voluntary flexion possible* (*Case 8*)



(*c*)

some weeks, until, in fact, the ends of the divided tendon become separated, this means that the intact lateral tendons slip to the front of the joint and now flex it, resulting in a hyperextension of the distal interphalangeal joint, which becomes flail, and flexion of the proximal interphalangeal joint.

Injuries to Extensor Tendons of the Fingers

Treatment

The principles of treatment of extensor tendon injuries do not differ in the main from those governing the treatment of flexor injuries.

Grafts are not used distal to the metacarpo-phalangeal joints but are used for the dorsum of the hand when there is tendon loss.

If there are secondary joint changes the best treatment is arthrodesis of the proximal interphalangeal joint in enough flexion to give adequate function.

Active exercises after sutures of extensor tendons are usually started within 3 weeks following the operation

Rehabilitation is complicated by two factors: (1) the use of the extensors is less obvious to a patient than the use of the flexors and, therefore, re-education is more difficult, (2) the extensors are weaker than the flexors and the rehabilitation of power is often difficult

Rehabilitation

The treatment of sutures of the extensor tendons in the dorsum of the hand presents no problems Provided there are no complications such as scarring or joint involvement, patients regain power rapidly Most patients have achieved full function within 4–6 weeks after suture.

Tendon sutures over the phalanges—Treatment starts 3 weeks after suture, and during the first week the physiotherapist supports the finger and encourages active extension within the inner range

The patient should be shown the movements passively several times. He should then attempt the movement with the physiotherapist's assistance and then finally on his own By the fourth week resistance should be added. When full extension is achieved, the patient should then be asked to hold the finger in extension for a period of 10–15 seconds If the movement is very weak the patient will attempt to trick by flexing the joint; the relaxation of flexion will then lead to a spurious idea of extension The re-education of movement at the terminal joint is not easy as this is normally a weak movement.

The joint should be re-educated with the terminal interphalangeal joints of the other fingers acting as a group The power of grip and general function of the hand must also be re-educated

Tendon sutures over the dorsum of the hand—Treatment starts 3 weeks after operation For the first week of treatment, active exercises within the inner range with minimal resistance is given Again the patient should be assisted to give him the idea of the movement required. By the fourth week resistive work can be given. The physiotherapist should sit alongside the patient With the interphalangeal joints fully flexed and the wrist slightly extended the patient is asked to straighten the metacarpo-phalangeal joints against increased resistance When full extension is achieved he should be asked to hold it for a good quarter of a minute, and the tendons should be seen to stand out strongly on the dorsum of the hand

Finally, the metacarpo-phalangeal joints should be extended while the interphalangeal joints are held in the straight position (Fig 14)

If there is poor active extension the patient is asked to flex the metacarpo-phalangeal joints with the interphalangeal joints extended, the palm being held

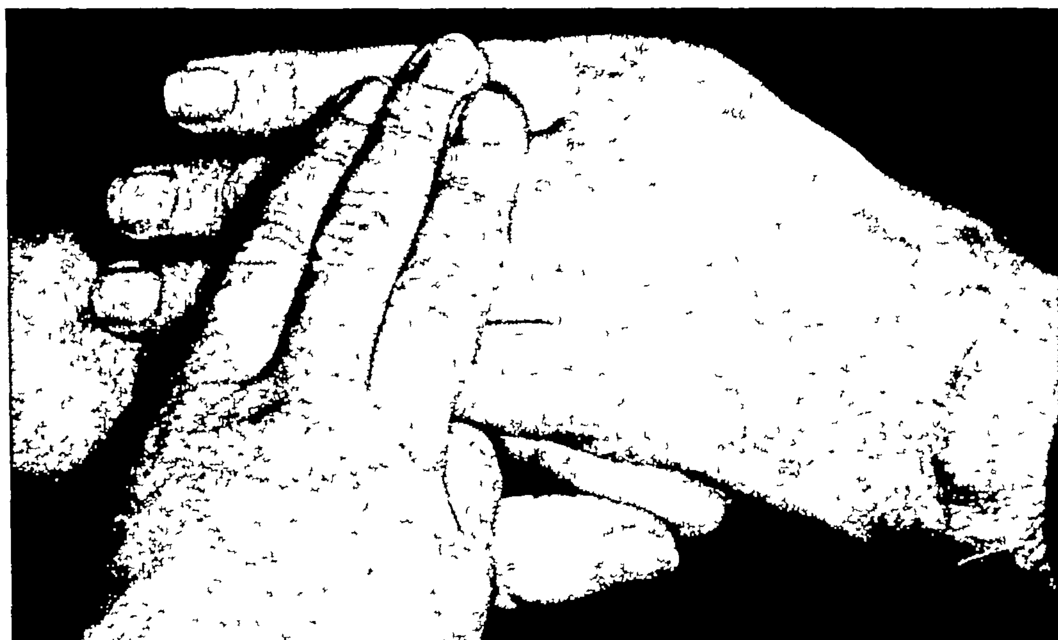


FIG 14 —*Re-education after extensor tendon suture of the fingers*

down on the table The patient then attempts to extend the metacarpo-phalangeal joints against resistance, this calls into play the synergistic action of the extensors—often they can be coaxed into acting as synergists before they will act as prime-movers The patient is asked to get as acute an angle as possible between the finger and the palm, this is a really strong exercise but the physiotherapist must take care to press down on the wrist to prevent wrist flexion

The next exercise is to ask the patient to raise the finger off the table at the metacarpo-phalangeal joint The physiotherapist presses down on the metacarpals to prevent flexion, then over the proximal phalanx, then the middle phalanx and finally over the distal phalanx, asking the patient to resist as much as possible against each one By this means the leverage is greatly increased The other fingers will automatically extend as well, and this should be encouraged as it is a good indication that the patient is performing the exercise correctly

The patient is then given abduction and adduction exercises for the fingers with increased resistance

It is important to re-educate all the intrinsic muscles of the hand in extensor tendon injuries owing to their insertion into the extensor expansion

Injuries to Extensor Tendons of the Thumb

Treatment

To re-educate the extensor pollicis longus tendon the physiotherapist supports the thumb in the web of her hand The patient flexes and adducts the inter-phalangeal joint strongly against the dorsum of the physiotherapist's hand, at the same time attempting to lift back the proximal phalanx, this brings the extensors strongly into action (Fig 15 *a* and *b*) Pinch grip and opposition are re-educated as the extensor is an integral component of these functions

In the rehabilitation of all extensor tendon injuries, whether of the finger or





(*a*) (*b*)

FIG 15 —*Re-education of extensors of the thumb* (a) *with and* (b) *without the physiotherapist's support*

thumb and at whatever site they are injured, the grip must be trained by progressive resistance exercises

GAMES SUITABLE FOR PATIENTS RECOVERING FROM TENDON SUTURE

(1) Flick such light material as cotton-wool, progressing later to hard objects such as marbles

(2) Balance a penny on the back of the terminal phalanx and attempt to transfer it to the back of each terminal phalanx in turn, one from another (Fig 16 *a*)

(3) As power improves the same game is used but with marbles

(4) The patient is asked to hold a match across the back of the affected terminal phalanx, the two fingers on either side are pressed down on top of the match and an attempt made to break it This shows up the extensor tendon action at the wrist very well (Fig 16 *b*)

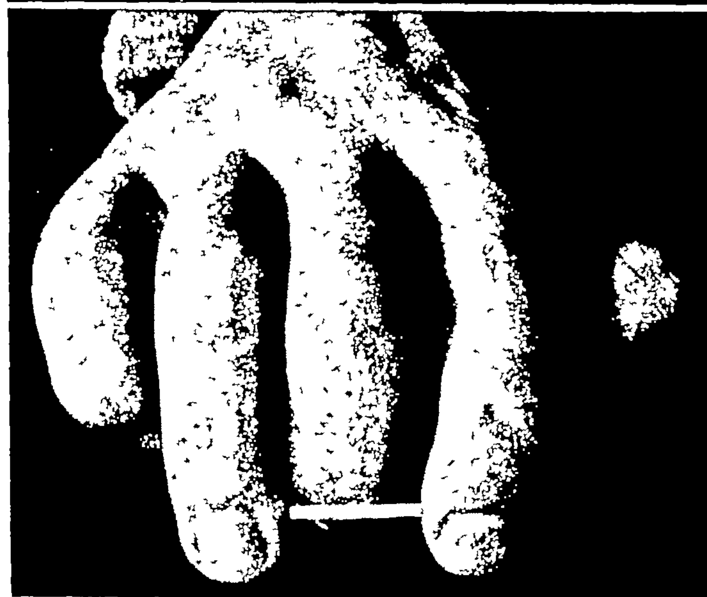
(5) A rubber band is placed around the wrist and another hitched to it which goes up to the volar surface of the finger and pulls over the back of the finger at different levels starting at the proximal phalanx and working to the tip where leverage is greatest, the patient attempting to extend the finger against the resistance of the rubber band The rubber band can also be placed over all the fingers and the thumb at about the level of the proximal interphalangeal joints, and the patient separates the fingers and thumb against the resistance of the band Following this each finger in turn is lifted in and out (Fig 16 *c*)

(6) Rolling and unrolling a crepe bandage and later a rubber bandage as described for the flexor tendons is useful

(7) Tiddleywinks is excellent for the later stages of re-education of extensor tendon action.



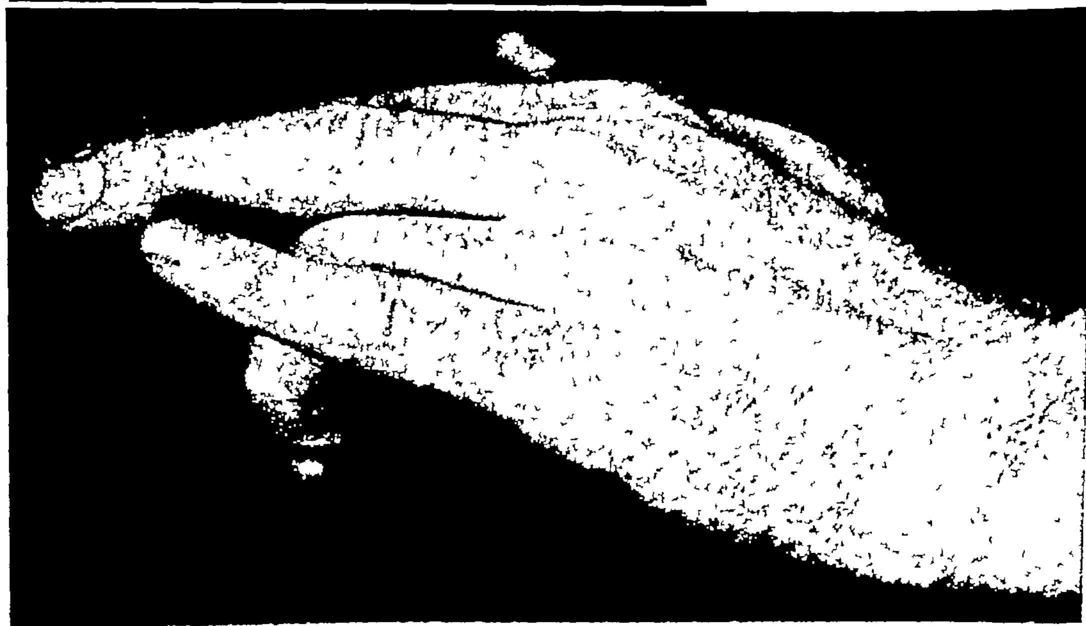
(*a*)



(*b*)

FIG 16 *a*, *b* and *c* —*Games used for re-education after extensor tendon suture of the fingers*

(*c*)



Occupational therapy

Early stages

For the first 2 weeks of treatment, that is, the fourth and fifth weeks after operation, craft work should be chosen with a view to working the tendon in its inner range only

Basketry is ideal at this stage, as is coil pottery, provided that there are no open wounds, and papier mâché work (spherical form) Weaving can be used with adaptation of a concave disc working in pronation and supination, alternating with a grip handle to produce wrist flexion and extension, this should be built up to give the amount of flexion required in the metacarpo-phalangeal joints. Draughts are used wide enough in diameter to make the patient abduct all the fingers and thumb so that resisted extension is produced Rug weaving is useful provided that the width of the shuttle is carefully adjusted

Children can be given finger painting and marionettes, the strings of the puppets being attached to rings which are slipped over the fingers Screwing wooden toys, net hand-ball with balloons, simple basketry, jigsaw puzzles with extra large pieces, draughts and weaving, as already described, are all appropriate

By the fifth week the resistance can be increased, filing, jack-planing, metal cutting, sandpapering—using only the fingers—and pottery, including wedging, all give good resistive work to the extensors The loom can be adapted to give wrist flexion and extension with strong resistance Typewriting and piano playing are very useful for those with knowledge of these activities Flip football and blow football for power and grip should be played daily

It should be noted that in tendon repairs when the metacarpo-phalangeal joints are in full flexion, it is necessary to allow some extension so that the tendon can be helped to initiate contraction To this end a sandpaper block with a curved surface allowing a few degrees of flexion at the metacarpo-phalangeal joints, and the paper surface on a slight curve, with a strap across the back of the hand and across the fingers, will produce an extensor thrust in both wrist and fingers A glove can be made for polishing so as to encourage this thrust Large adaptations to looms are useful, or any other craft giving abduction of the fingers, to allow the metacarpo-phalangeal joints to fall into passive extension, the flexors and abductors stabilizing the position

Late stages

In the final stages of rehabilitation strong work may be required for those patients returning to strenuous jobs Cement work is useful, using a strap across the back of the hand in place of the handle of the trowel Bricklaying, plastering, wood veneering, lino printing, all offer strong work for the extensors Specifically for the thumb, cutting out any stiff material is valuable

These crafts apply initially to all tendon lesions whether at the interphalangeal joints, the metacarpo-phalangeal joints, or on the dorsum of the hand

In general, for the interphalangeal joints, crafts are emphasized which embody strong intrinsic action, such as lino printing, small screwdriving and sandpapering with the fingers

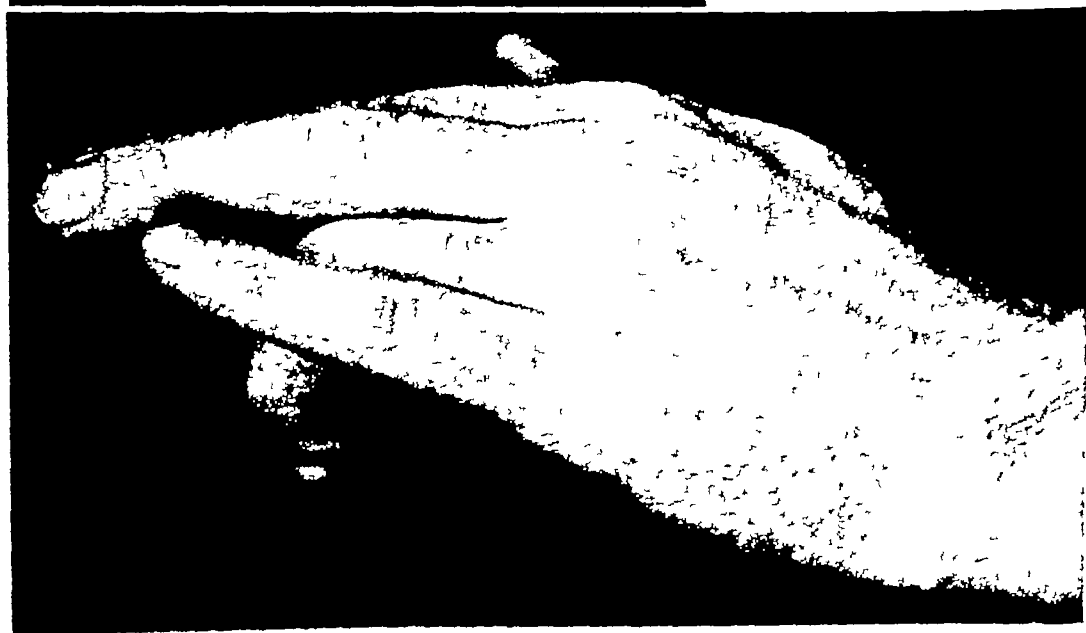
In both physiotherapy and occupational therapy departments, the importance of restoring a good grip and function of the flexors of the fingers and thumb must never be overlooked



(*a*)

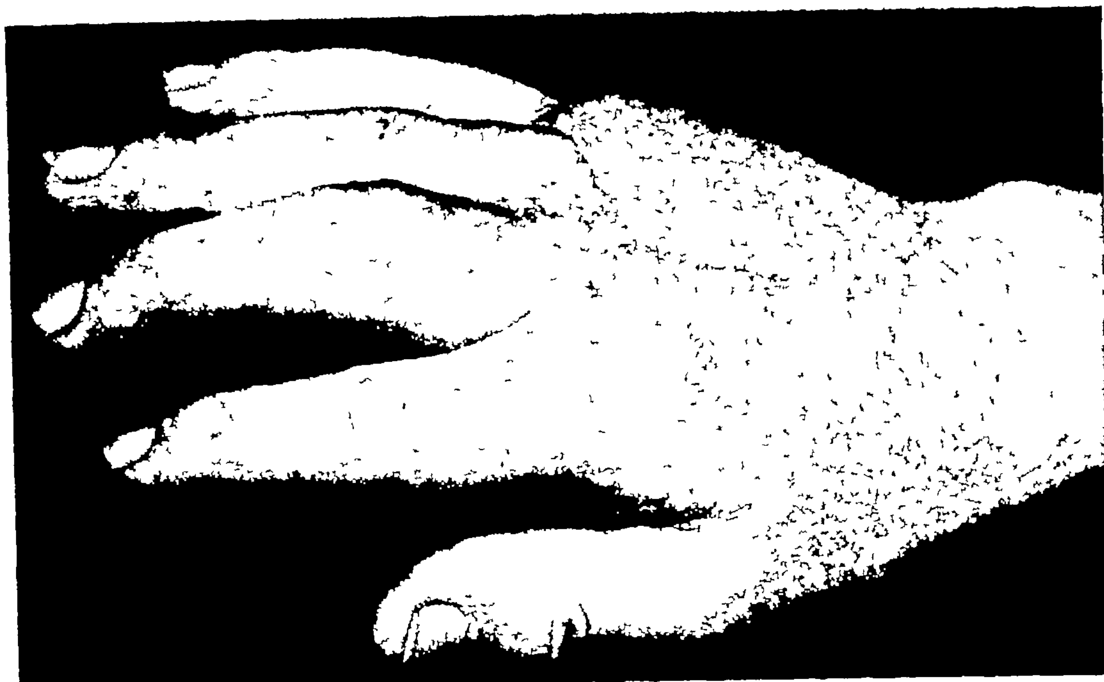


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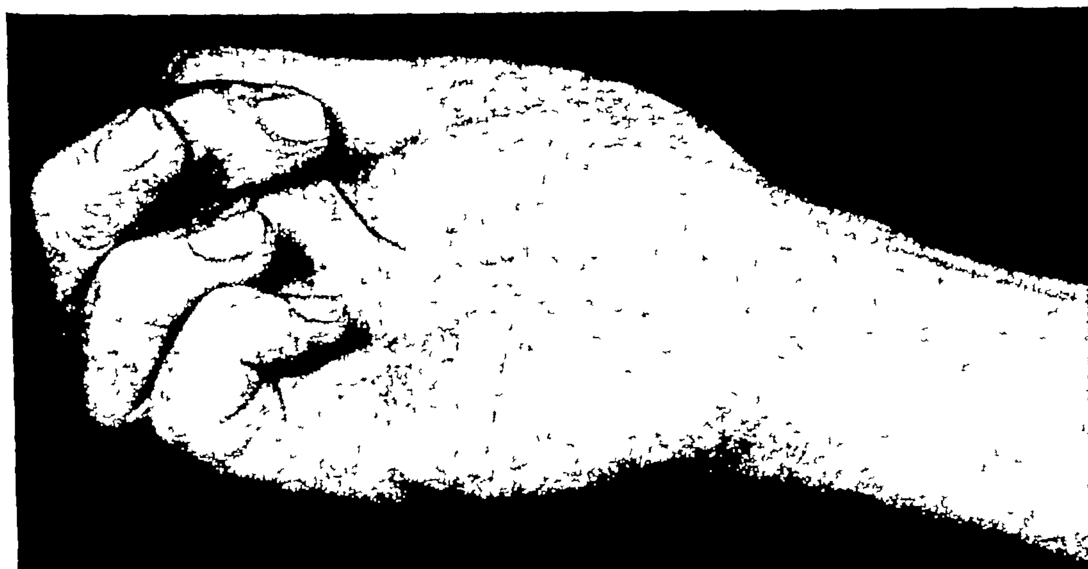


(*c*)

FIG 16 *a*, *b* and *c* —*Games used for re-education after extensor tendon suture of the fingers*



(*a*)



(*b*)

FIG 17—*Result following skin grafting and grafts to extensor tendons of the middle, ring and little fingers* (a) *Extension,* (b) *flexion* (*Case 2*)

physiotherapy department and the gymnasium together with occupational therapy was instituted Three weeks later (7 weeks after grafting) the metacarpo-phalangeal joints were still very stiff and rock-like Accordingly, passive movements, stretches, and the wearing of a progressive stretch splint were started Electrical stimulation of the extensor tendons was also given in this case, as the tendons were slow to develop activity in view of the stiff metacarpo-phalangeal joints Three months later movements of the fingers were index 150–75 degrees, middle 160–102 degrees, ring 150–83 degrees, and the little 175–90 degrees, the patient could just raise his fingers off the desk At this stage he was discharged to his flying duties (Fig 17 *a* and *b*)

Results

The following are the average periods of time under treatment for each type of tendon lesion in the uncomplicated case

Lesions over the dorsum of the hand—These patients should be at full work within 6 weeks of tendon suture

Lesions at the metacarpo-phalangeal joints—The average time for return to full work in these cases is 5–7 weeks

Lesions over the proximal phalanx—Full function is obtained in 4 weeks in these cases

Lesions at the distal interphalangeal joint—The average duration of treatment here is longer, being as much as 8 weeks, and generally there is a certain degree of extension lag in these cases

Adverse factors

The commonest complicating factors in extensor tendon injuries are accompanying fractures, gross scarring, oedema, soft-tissue damage and infection

As for all hand lesions, if the patient is not interested in his condition, the result will inevitably be poor Scarring over the back of the hand or finger is dealt with by vigorous and frequent oil massage In such cases there is likely to be considerable limitation of movement in the metacarpo-phalangeal joints In severe cases, these require plaster stretch splinting in addition to frequent passive movements throughout the day

Case histories

Case 1—This patient cut the dorsum of the right wrist on a pane of dirty glass All the extensor tendons to the middle, ring and little fingers were severed A cellulitis developed with gross oedema of the hand This was well controlled with penicillin, but it was not possible to operate for 2 months after the injury At operation gross scarring was found with considerable loss of tendons The tendons were grafted and rehabilitation was started 1 month later At this stage, active dorsiflexion of the wrist was 50 degrees, but there was no active palmar flexion, the index, middle and ring fingers were held with the metacarpo-phalangeal joints at 100 degrees with little or no passive range, and the little finger at 125 degrees It was impossible for the patient to raise these fingers off the table After 6 weeks' treatment, there was 65 degrees palmar flexion of the wrist, an almost full range of passive movement at the metacarpo-phalangeal joints and the patient could raise all the fingers off the table together, though not individually On discharge, function was good and improving daily

It has been found that with cases of this type, as soon as hand function is good and there is definite action of the extensors, treatment can be stopped as further improvement with time and use is assured

Case 2—This patient, involved in a road accident, sustained multiple lacerations of the face, neck, shoulders, and loss of skin of the right hand with division of extensor tendons An immediate pedicle was raised to cover the hand One month later grafts from the toes were put into the middle and ring fingers A marked reaction was noted in the soft tissues Rehabilitation started 1 month after the grafting The main disability was gross limitation of movement of the metacarpo-phalangeal joints

Movements recorded in the fingers were index 130–105 degrees, middle 150–130 degrees, ring 145–128 degrees, little 170–121 degrees There was no active extension of the index, middle or ring fingers Extension of the little finger was present and the patient could raise it 0 4 inch off the desk A full programme of re-education in the

CHAPTER 3

PERIPHERAL NERVE INJURIES

INTRODUCTION

ALL THREE nerves supplying the hand are liable to damage which may well result in very severe loss of function

Damage to the median nerve is the most serious, but the severity of injury depends on the degree of soft-tissue damage and the type of injury

A lesion of the ulnar nerve which does not recover does not produce so much functional loss as might be thought However, severance of the ulnar nerve, with damage to the tendons and a great deal of soft-tissue damage with subsequent fibrosis and stiffening of the joints can produce a crippled hand for life

In this chapter, the cause and significance of peripheral nerve injuries and detailed assessment of damage and appreciation of subsequent recovery are discussed The results of various types of lesions, with and without complications, are presented in the light of the authors' experience, and the various treatments of physiotherapy, occupational therapy, remedial exercises, lively splintage and retraining are all fully described This chapter is based on the personal study of some 200 peripheral nerve injuries involving the hand

CAUSES OF INJURY

Trauma

Radial nerve

The following are the main causes of injury to the radial nerve in order of frequency

Fractures of the humerus involving the nerve in the spiral groove, direct blows to the nerve in the upper arm, traction lesions, damage to the nerve by pressure in sleep—as in a Saturday night palsy—fractures of the radius and ulna, and direct blows to the forearm involving the posterior interosseus branch

In the series of peripheral nerve injuries discussed by Brooks in the Medical Research Council report of 1954, of 102 nerve injuries due to fractures, 44 were radial palsies following fractures of the humerus Seventy per cent of the cases in the Medical Research Council series achieved spontaneous recovery, in our smaller series all recovered

Median nerve

The common cause of damage to the median nerve is by falling on glass or putting the hand through a glass window pane and severing the nerve at the wrist.

Next in frequency are lacerations of the wrist due to a multitude of causes such as cuts by glass, knife wounds and falls on hard objects Then come various lesions at the elbow—lacerations, fractures and ischaemic paralysis

Other causes are traction injuries involving the median nerve roots, and compression of the nerve in the carpal tunnel by the flexor retinaculum

Ulnar nerve

The commonest site of injury of the ulnar nerve is at the wrist, and by far the

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In this condition the flexor muscles of the wrist and fingers become necrotic The resulting fibrosis results in a severe flexion deformity of wrist and fingers

TYPES OF LESIONS

There are three main types of nerve lesion classified according to the amount of damage sustained These are neurapraxia, axonotmesis and neurotmesis

Neurapraxia

Neurapraxia is defined as loss of conduction in a nerve without degeneration The signs of a neurapraxia are paralysis in muscles supplied by the nerve with minimal wasting, and electrical signs showing that there has been no denervation It may often be possible to stimulate the nerve below the point of block and thus show that there has been no extensive damage to it Stimulation above the block does not cause contraction of the muscles supplied by the nerve except in a few cases when a very high current might penetrate through the block Common causes of neurapraxia are blows and pressure on the nerve, which is not sufficient to cause damage to the nerve structures resulting in denervation

Recently, careful electrical investigations into cases of neurapraxia have revealed that a pure neurapraxia is very rare Almost always there is some slight evidence of degeneration This, however, is seldom sufficient to be obvious clinically when the block recovers, but it is of interest to know that injuries which cause a neurapraxia almost always produce some denervation, however slight

Usually, one of the functions of the nerve is spared to some extent Very often there is not as complete a sensory loss as would be expected in a complete lesion of the nerve, though motor paralysis is usually complete Within the sensory modalities the proprioceptive fibres are most vulnerable A neurapraxia usually recovers completely within 6 weeks after onset and often within 4 weeks Patients have, however, been seen in whom a neurapraxia has persisted for up to 3 months Careful electrical tests will relieve the patient's anxiety It must be emphasized that the electrical signs of denervation do not appear for 10–14 days after injury and, therefore, tests should not be done until after this time has elapsed Clinically, there is minimal wasting and no circulatory disturbance

Axonotmesis

Axonotmesis is defined as injury to the nerve in which the axon is damaged to such an extent that wallerian degeneration occurs The damage is not sufficient to affect the nerve sheath, the fact that the sheath is intact means that the nerve fibres can grow down their own tunnel Suture is therefore not needed and recovery is usually almost perfect Re-education is theoretically not required because the fibres make contact with the correct end-organs Surgical exploration may, of course, be necessary in axonotmesis if there is pressure by some agent such as callus or tumour, or the nerve is under tension due, for example, to a neuroma

Neurotmesis

Neurotmesis is defined as an injury to a nerve involving both axis cylinder and sheath Suture is essential to provide the growing axon with a tunnel otherwise it will grow in a haphazard fashion and very few nerve fibres will achieve their destination Re-education is vital as the axons do not by any means always return to their original end-organs

commonest cause is, again, putting the hand through a glass window pane The next commonest are lacerations due to knives and glass Lesions at the elbow are common, that most often seen is traumatic ulnar neuritis, for which there are several causes Many years after fracture of one of the bones of the elbow joint, pressure on the ulnar nerve may be caused by gradual progressive deformity (cubitus valgus) Arthritis of the joint is a more rare cause

Again, lacerations occur at the elbow and traction lesions involving the nerve roots in the neck

At the wrist an affection of the ulnar nerve known as neuritis of the deep branch of the ulnar nerve can occur This results in paralysis of the interossei, the medial two lumbricals and the adductor pollicis, and weakness of the flexor brevis if the nerve supplies it, with no sensory loss It follows commonly from long-continued pressure on the hypothenar eminence on handle-bars in despatch riders and other people who exert pressure on this part of the hand over many years

Median and ulnar nerve lesions combined

It is not uncommon to see patients who have sustained a very severe traumatic lesion at the wrist where both the median and ulnar nerves and all the tendons, and the two arteries, are severed This is one of the most disabling conditions of all hand injuries, and is most commonly due to plunging the hand through a glass window pane

Infective and toxic

Radial nerve palsies due to lead poisoning and alcoholic peripheral neuritis are classic examples In Eastern countries, leprosy is a frequent cause of multiple nerve injuries in the hand This is a most disabling condition resulting in tragic deformity in untreated cases

Pressure

Common causes

Common causes of pressure on the peripheral nerves are prolapsed discs, osteophytosis in the cervical spine causing injury to the nerve roots of C 7, C 8 or T 1, and pressure of haematomas after soft-tissue damage

Seddon (1952) and Brooks (1952a) have described a number of patients in whom a ganglion on the deep branch of the ulnar nerve in the palm caused nerve damage Removal of the ganglion resulted in complete cure of the symptoms

Rare causes

The author has seen a patient in whom painful fatty lipomas caused paralysis of the radial nerve in one arm and of the ulnar nerve in the other arm Two cases of nerve lesions due to periarteritis nodosa have been seen

Other traumatic causes of nerve injuries

Industrial accidents are often the cause of injuries to peripheral nerves and tendons, both in the wrist and in the upper arm Such accidents involving the peripheral nerves also produce extensive damage to the soft tissues, particularly in crush injuries

Gunshot wounds can damage the nerves anywhere throughout their course

Badly applied plasters cause ischaemia with resulting degeneration of the nerves A specific type of ischaemic paralysis is Volkmann's contracture due either to badly fitting plaster or following dislocations and fractures of the elbow joint

mixed neurapraxia, axonotmesis and neurotmesis Upper trunk lesions are commonest, followed in frequency by lesions of the whole trunk

Our findings conform to those described in the Medical Research Council Report (1954)

Recoverable upper trunk lesions should show some sign of recovery within a year of damage The tendency now is not to carry out reconstructive surgery, such as arthrodesis of the shoulder or pectoral transplant, until at least a year has elapsed

One is pleasantly surprised at the number of patients who show worthwhile recovery many years after severe traction lesions

As the axons have such a long way to travel, functional recovery in hand muscles after severe brachial plexus lesions is negligible

Sensory recovery is more hopeful, though here again the end-organs may well have atrophied

If good function returns in the proximal muscles, a combination of lively splintage and reconstructive surgery can often give the patient a useful limb

PATHOLOGY

After section of a nerve, certain changes take place in both muscle and nerve The changes in nerves are known as wallerian degeneration The nerve degenerates to the proximal node of Ranvier, the axis cylinder disintegrates and the debris is cleared away by macrophage activity The empty tube is left along which the large cells of Schwann proliferate If the lesion is a neurotmesis there is, of course, no tunnel present

In the muscle some change in the arrangement of the fibres is seen by the end of the sixth week Subsequently, there is progressive kinking of the fibres, the coarse striation becomes less obvious and finally they begin to disrupt after 3 years By the end of the twelfth week connective tissue elements increase and invade the terminal Schwann tubes Gradually, the muscle is replaced by fibrous tissue If re-innervation does not occur the muscle becomes fibrotic after about 2 years

The significance of these changes is that nerve suture must be carried out as early as possible in order that the best muscle function will result As the muscle becomes fibrotic by 2 years after denervation, it is essential to perform nerve suture so that re-innervation occurs within this period Good function cannot be expected in muscles a long distance from the site of lesion For example, repair of the median nerve at its origin in the neck would be unlikely to give good function in the thenar muscles as it would take longer than 2 years for the nerve to grow down to them

CLINICAL PICTURE

The clinical pictures presented by damage to each of the nerves in turn will now be discussed

Certain changes common to all peripheral nerve injuries are seen, they can be divided into motor, sensory and sympathetic effects

Motor

The obvious result of damage to the motor part of the peripheral nerve is motor paralysis. However, there are certain trick movements which may well confuse

As discussed under neurapraxia, there may well be a condition in which part of the nerve is blocked and part is actually degenerated

The classical signs of nerve degeneration, both clinical and electrical, are seen in both axonotmesis and neurotmesis, these are discussed in detail in Chapter 4

The indications for surgical exploration in nerve injuries depend on whether the lesion is open or closed and on the type of injury that originally caused the nerve damage

In complete lesions, exploration is indicated when there is an open wound, and in closed injuries if recovery is delayed longer than would be expected after waiting for the nerve to grow at a rate of 1 millimetre a day, or if there is obvious compression of the nerve by callus, tumour or aneurysm

In ulnar neuritis where function is deteriorating, exploration is required in order to transpose the nerve to a site in front of the elbow embedded in muscle, where it will no longer be compressed

Traction lesions have a notoriously bad prognosis This gloomy outlook is to some extent justified with lower root injuries but is less so with upper root lesions

Seddon (1952) and Brooks (1952b) have given up exploring such lesions but a useful test designed by Bonney (1954) distinguishes pre-ganglionic from post-ganglionic lesions This involves measuring the reflex response to histamine in the skin When the roots are avulsed, axon reflexes will be obtained in the skin of the arm because the peripheral axons of the posterior root are in continuity with their nutrient cells in the posterior root ganglion Thus, the absence of axon reflexes is a better prognostic sign than their presence Clearly the pre-ganglionic lesion is hopeless and any reconstructive procedure thought desirable can be embarked on early in such conditions

When nerve lesions complicate fractures, the damage may have been caused either at the moment of fracture, as when the radial nerve is damaged at the site of fracture at the mid-shaft of the humerus, it may be due to a traction lesion as in many road accidents, or it may be due to subsequent developments such as pressure of callus or slowly progressive deformity as in ulnar neuritis at the elbow.

The distinction between a traction lesion and a lesion of the nerve at the site of fracture can easily be made because traction lesions will cause damage proximal to the fracture site Furthermore, there is often a sparing of some function in a traction lesion

The best results in nerve injuries associated with fractures are in posterior interosseus, median and ulnar nerve lesions Certain types of nerve palsies do badly, one example of this is a circumflex palsy, when the deltoid in many cases does not recover

Brachial plexus lesions

The brachial plexus can be damaged by a variety of means fractures involving the plexus, gunshot wounds, blows and swellings such as tumours pressing on the plexus The commonest cause of injury is a traction lesion which pulls on the plexus and may cause either a partial or complete lesion.

Traction lesions are frequently found in road accidents, particularly motor-cycle accidents where the patient tends to hold on the handle-bars while the rest of the body is dragged from the machine This puts severe traction on the roots in the neck Damage may vary from complete paralysis of the whole plexus to

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After section of a nerve, certain changes take place in both muscle and nerve The changes in nerves are known as wallerian degeneration The nerve degenerates to the proximal node of Ranvier, the axis cylinder disintegrates and the debris is cleared away by macrophage activity The empty tube is left along which the large cells of Schwann proliferate If the lesion is a neurotmesis there is, of course, no tunnel present

In the muscle some change in the arrangement of the fibres is seen by the end of the sixth week Subsequently, there is progressive kinking of the fibres, the coarse striation becomes less obvious and finally they begin to disrupt after 3 years By the end of the twelfth week connective tissue elements increase and invade the terminal Schwann tubes Gradually, the muscle is replaced by fibrous tissue If re-innervation does not occur the muscle becomes fibrotic after about 2 years

The significance of these changes is that nerve suture must be carried out as early as possible in order that the best muscle function will result As the muscle becomes fibrotic by 2 years after denervation, it is essential to perform nerve suture so that re-innervation occurs within this period Good function cannot be expected in muscles a long distance from the site of lesion For example, repair of the median nerve at its origin in the neck would be unlikely to give good function in the thenar muscles as it would take longer than 2 years for the nerve to grow down to them

CLINICAL PICTURE

The clinical pictures presented by damage to each of the nerves in turn will now be discussed

Certain changes common to all peripheral nerve injuries are seen, they can be divided into motor, sensory and sympathetic effects

Motor

The obvious result of damage to the motor part of the peripheral nerve is motor paralysis. However, there are certain trick movements which may well confuse

the examiner in his assessment of the extent of paralysis, they may also be confusing when assessing re-innervation These trick movements have been surprisingly neglected in the literature, and seem to be little known, consequently they will be discussed in detail under the appropriate headings Russel and Harrington (1944) and Sunderland (1944) have both contributed to this subject

Wasting is an inevitable accompaniment of axonotmesis or neurotmesis, but not of neurapraxia It first becomes obvious in about 4–6 weeks after the lesion, 2 months after damage, wasting develops rapidly and becomes maximal about 3 months after injury It is important to explain to the patient that the wasting will become more progressive, otherwise he may feel that the treatment he is receiving is doing him harm and he will naturally be worried to see a progressive loss of muscle bulk The deep reflexes will, of course, be diminished and finally lost altogether with muscle paralysis Tone is absent Deformities will arise as a result of the muscle paralysis due to over-action of the antagonist muscle groups, these will be described in detail later

Sensation

In a complete lesion all modalities of sensation, except joint position sense, are lost In many cases the nerves subserving joint sensation travel via the tendons and not through the large nerve trunks at the wrist If there has been an isolated nerve lesion without tendon damage, position sense may be retained It will usually be a coarse appreciation but it will be present This may cause confusion and suggest a partial lesion, but only if the underlying anatomical facts are not realized There will be the appropriate anaesthetic areas of skin It is important to realize that sensory supply by no means always follows the description given in the text-books

Various common anomalies have been described in Chapter 1, the commonest concerns the radial nerve which may well subserve no sensation at all It is very rare in a patient with a radial nerve lesion to have any part of the skin completely anaesthetic

Soon after injury the area of complete sensory loss contracts, due to the adjacent nerves taking over sensation in the periphery of the affected area It is not to be taken to mean that there has been a partial nerve lesion only

The skin becomes scaly, the nails brittle and curved, and the soft tissues become atrophic so that there may be as much as ¼ inch loss in circumference of an affected finger

Vasomotor disturbance

The changes in circulation are clearly divided into two phases In the early stages after denervation the affected skin is warm—this appears to be due to paralysis of the vasoconstrictor nerves Some 3 weeks later the skin becomes cold Usually only the area of skin supplied by the affected sensory nerve becomes cold, but sometimes the whole hand is colder than the normal side The temperature of the denervated skin depends very much on the climate—the colder the weather the colder the denervated area At this time, too, the skin takes on a characteristic reddish colour which becomes purple when cold There is a clear-cut division between the affected and the normal skin

Atrophic lesions are most likely to occur in these early stages before the patient has learnt that he must be extremely careful with the anaesthetic skin, burns and

blisters which may become infected are commonly caused by cigarettes and leaning with the hands behind the back on a radiator It is very important to warn patients about the possible dangers of anaesthetic skin and they should always be encouraged to wear gloves whenever the weather becomes cold

Later, the scaliness of the denervated skin disappears, the texture becomes smooth and shiny, and the skin creases causing ridges to become much more obvious

The vasomotor changes are not fully understood Barnes (1954) suggested that the loss of the axon reflex may well be an important factor, this may be necessary to normal defence and nutrition of the skin

It must not be forgotten that there are general effects of localized lesions of the hand Later, the lack of use of the hand due to paralysis may produce stiffness in other joints of the limb

The psychological effect of the paralysis must never be forgotten

In peripheral nerve injuries, particularly severe ones involving the hand, it is more than ever important to explain to the patient exactly why he has the deformities, the paralysis and the loss of feeling, what is being done to help and what the ultimate result is expected to be Such patients require continual encouragement throughout the long months of waiting for nerve regeneration Many get depressed at seeing wasting progress in the early stages This must be carefully explained

DEFORMITIES IN SPECIFIC NERVE LESIONS

Median nerve lesions

Lesions of the median nerve, at whatever site, produce some deformity in the hand

Deformities at the wrist

The deformity of median nerve paralysis at the wrist is commonly known as the monkey hand, because of its flat appearance due to wasting of the thenar eminence and lack of opposition The thumb is held beside the index finger because the internal rotator muscles of the thumb, the abductor brevis and opponens are paralysed and, therefore, their antagonists, the extensor pollicis longus, exerts unopposed action in pulling the thumb round beside the index finger in extension There is paralysis of the first and second lumbricals so there may be a hyperextension deformity at the metacarpo-phalangeal joints of the index and middle fingers (Fig 18)

Lesions in the elbow and the neck

Lesions in the elbow or in the neck will result in motor paralysis of the flexors of the fingers and wrist and of the pronators, but not in any more marked deformity than is seen with lesions at the wrist joint The only extra deformity seen with damage at the elbow is that there will be hyperextension of the wrist due to overaction of the wrist extensors unopposed by the paralysed wrist flexors

Functional disability

Most patients with a median nerve lesion find difficulty in picking up both big and small objects, and are generally clumsy, finding that they cannot hold objects with confidence, nor can they tell what is in their hands unless they look They cannot fasten buttons or shoelaces, or cut their finger-nails or cut up meat To hold a fork is difficult, as is shaving

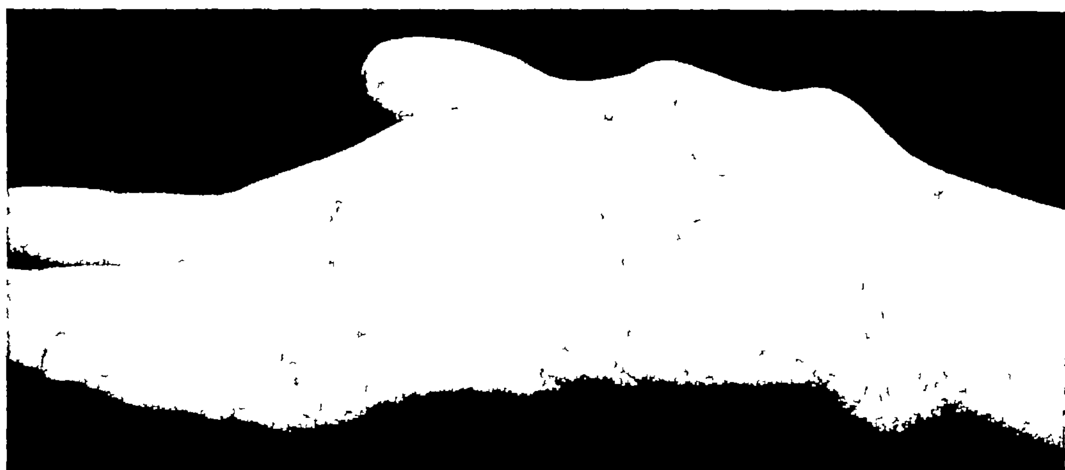


FIG 18 —*Deformity in a combined median and ulnar nerve injury*

Ulnar nerve lesions

The classical deformity due to ulnar nerve paralysis is the " claw hand ", this will occur whether the lesion is present at the wrist, the elbow, or in the neck The metacarpo-phalangeal joints of the ring and little fingers are held in hyper-extension (usually about 30 degrees) This is due to the overaction of the extensor digitorum communis and the extensor digiti minimi whose main action is at this joint Their normal antagonists are the third and fourth lumbricals whose action is to flex the metacarpo-phalangeal joints, and they are, of course, paralysed

The interphalangeal joints of these 2 fingers are held in flexion (25 degrees at the proximal interphalangeal joint and 10–20 degrees at the terminal interphalangeal joint) due to the overaction of the flexors profundus and sublimis, which are unopposed by their paralysed antagonists, the interossei

If the lesion is at the elbow, there will be paralysis of the flexor profundus to the ring and little fingers, and consequently there will be only a slight flexion deformity of the interphalangeal joints due to the sublimis action, there being none at the terminal interphalangeal joints Paradoxically, a sign of satisfactory regeneration of an ulnar nerve lesion at the elbow, or in that region, is a gradual increasing deformity of flexion of the ring and little fingers, due to the recovery of the profundus muscle The paralysis of flexor carpi ulnaris does not produce a deformity, although on attempted ulnar deviation the wrist will go into extension due to unopposed action of the extensor carpi ulnaris

The claw hand in an ulnar nerve palsy mimics the position adopted by the " refined " when drinking tea

Functional disability

Most patients with an ulnar nerve lesion have functional disability which prevents them from holding a knife properly, they usually hold it between the index and middle fingers

Writing is difficult, due particularly to the loss of sensation in the little finger and hypothenar eminence with the hand on the paper Pulling tight and tying shoe laces is awkward, there is difficulty in fastening buttons and cutting finger-nails, shaving is also difficult

A few patients, however, learn to carry out almost all activities, and some 10 per cent do not regard the lesion as any disability at all

Patients with a median and ulnar nerve lesion combined, together with adherence of flexor tendons at the wrist, are seriously handicapped They suffer the same functional disabilities mentioned above

Radial nerve lesions

The characteristic deformity in radial nerve palsy is a wrist-drop The wrist is held in some 45 degrees palmar flexion due to the overaction of the wrist flexors unopposed by their antagonists—the paralysed wrist extensors The thumb is held in palmar abduction and slight flexion, due to the unopposed action of the short flexor and short abductor, their antagonists—the long abductor and short and long extensors—being paralysed

The metacarpo-phalangeal joints are held in about 30 degrees flexion due to the unopposed action of the lumbricals, the extensor digitorum being paralysed There is only slight flexion at the interphalangeal joints as the interossei extend

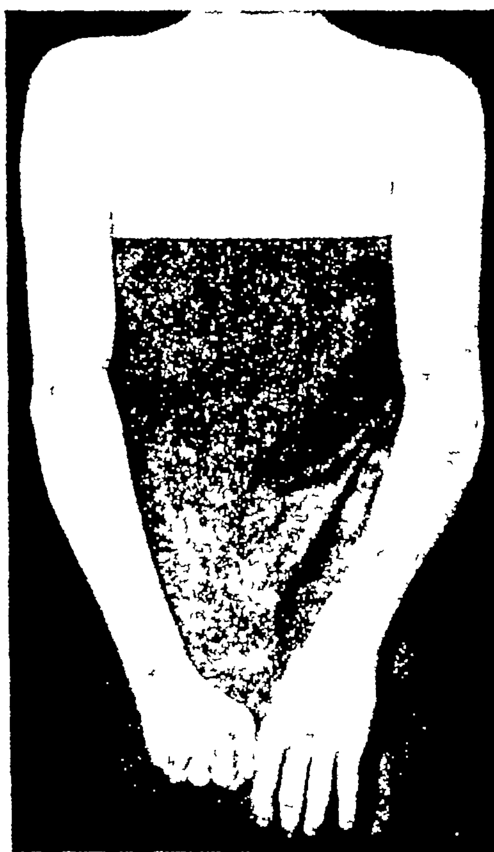


FIG 19 —*Deformity and wasting in a radial nerve palsy*

these joints and are, of course, unaffected, the slight flexion is that due to the wrist and metacarpo-phalangeal joints taking up a position of flexion which automatically results in slight flexion at the proximal interphalangeal joints

Attempts at ulnar deviation result in increased flexion and deviation due to the overaction of the flexor carpi ulnaris unopposed by its paralysed antagonist—the extensor carpi ulnaris Wasting of the extensor muscles of the forearm is obvious (Fig 19)

Functional disability

Patients with a radial nerve lesion cannot hold a knife or fork easily, nor cut their finger-nails They have difficulty in fastening buttons and brushing their hair Shaving and tying shoe laces are also difficult to manage Generally they have a poor grip and cannot put objects like glasses or cups down flat on a table

Treatment by lively splints

If the deformities are not prevented by splintage they may become permanent The need for corrective splintage in peripheral nerve injuries has been recognized for a long time, but only recently has it been appreciated that a good splint should do more than merely correct deformity, it should also encourage function

Many of the splints in common use—for example, the knuckle-duster splint for ulnar nerve palsy—only correct the deformity, they are not designed to encourage movement and, indeed, they often deter it

Many so-called trick movements are available in these nerve injuries, and if a splint is designed both to correct deformity and to make use of these movements for function, the patient will make much more use of his hand By this means movement patterns are not lost in the brain during the many months of paralysis, the circulation is kept at its best and, most important of all, the patient can often go back to work The type of splint that performs both of these functions is known as a lively splint and should always be used in patients with peripheral nerve injuries

The splints to be described are those found by experience in our Centre to be the best for the particular disability Each splint must be made specially for each individual patient, and the fitting must be reviewed at regular intervals The splint must be altered or a new one made should increase in wasting make it too loose or recovery of bulk make it too tight

It is essential that lively splints in nerve lesions should be light, easy to clean, of simple design, as aesthetically practicable as possible and made accurately to measure to ensure comfort Many patients came from different institutions with bulky splints which were only produced to please the doctors, many were covered in dust indicating that they may have been left on top of a wardrobe Patients will not wear a splint that is bulky, uncomfortable and rigid (Fig 20)

The test of the usefulness and good design of a splint is whether the patient wears it voluntarily There is a tendency among some workers to invent a theoretically brilliant contrivance with all manner of springs to substitute for loss of function, but which becomes a lively splint in the most literal sense of the word Often the patient becomes merely an appendage to his splint It represents a triumph to the engineer but a prison for the patient The making of the splints is described in detail at the end of the chapter

Lively splintage for median nerve lesions

The principle of the splint is to pull the thumb into palmar abduction and slight flexion, both to counteract the deforming action of the long extensor and to encourage opposition by the long flexor The function of the short abductor and flexor is to put the thumb into the opposing position, and this is what the splint does It is simply a piece of elastic attached to a wrist-strap which encircles the thumb pulling it into the required position (Fig 21)

Lively splintage for ulnar nerve lesions

The principle of the splint is to prevent hyperextension at the metacarpo-phalangeal joints If this is done effectively there will be no need to correct the flexion deformity at the interphalangeal joints because the support at the meta-carpo-phalangeal joints allows the extensor digitorum to act on the interphalangeal joints

To encourage function, the splint should allow a good range of movement at the metacarpo-phalangeal joints The splint has been found extremely useful in practice and fulfils both these needs, indeed, some patients have been able to return to work wearing this splint despite total nerve paralysis There should be support to the metacarpo-phalangeal joints by bars proximal and distal to them, connected by elastic at the sides, thus preventing hyperextension and allowing movement (Fig 22)



FIG 20—*Bulky splint for radial nerve palsy, which patients find unpopular due to restricted movement*

Splint for radial nerve palsy

The object of this splint is to prevent wrist-drop by putting the wrist into dorsiflexion to encourage function, the splint should be designed to allow flexion and extension of the wrist There is no necessity to arrange the splint so that the thumb is extended, as it will be found that once the wrist is in dorsiflexion the thumb tends naturally to assume a functional position The splint has a spring along the ulnar border of the forearm to allow flexion and extension It will be seen from Fig 23 that when the splint is worn the patient's hand takes up the position of function

With the support given, the interossei are now able to extend the fingers and a good grip from the flexors is obtainable

The splint is made up of a leather forearm piece with a side spring hinged at the wrist to allow flexion and extension, and a bar across the palm to give dorsiflexion and support the metacarpo-phalangeal joints (Fig 23)

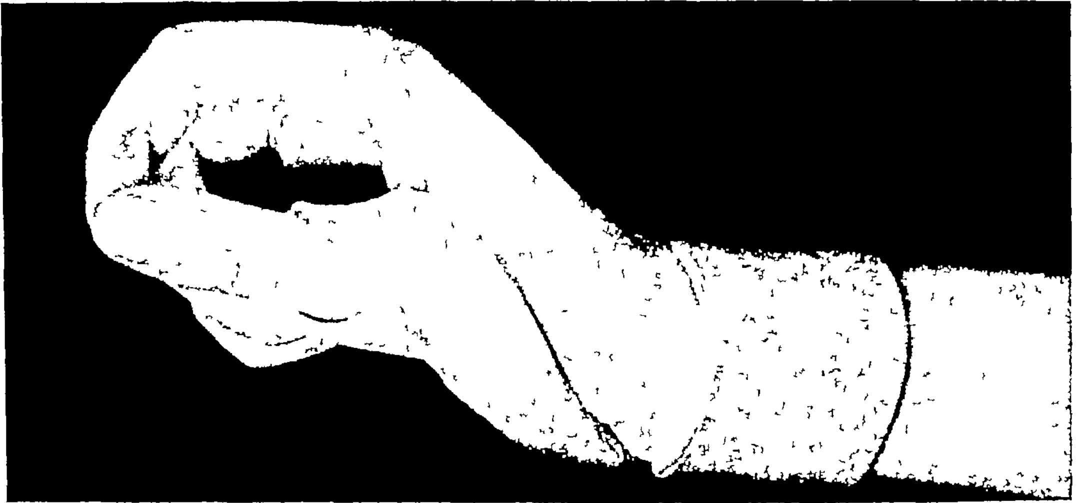


FIG 21 —*Lively splint for median nerve palsy*

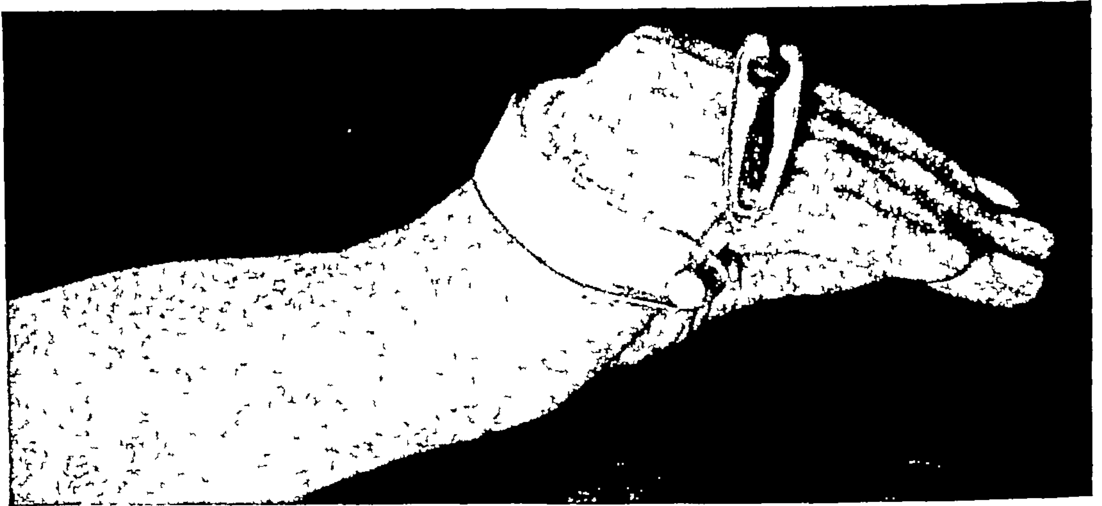


FIG 22 —*Lively splint for ulnar nerve palsy*

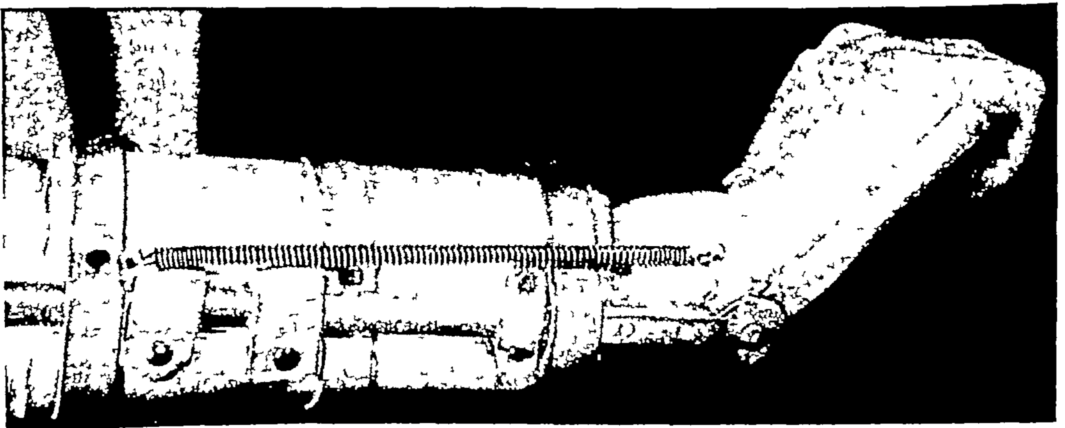


FIG 23 —*Lively splint for radial nerve palsy*

ASSESSMENT OF FUNCTION

Examination for muscle power

The study of muscle action in peripheral nerve injuries should always include the response to stimulation of the nerve trunks in order to demonstrate any anomalies of innervation These are much commoner in the hand than are generally realized and are dealt with fully in Chapter 1

When recovery is well advanced, the assessment of muscle action is best done functionally rather than in an attempt to chart the muscle accurately on the Medical Research Council scale

It is very difficult to isolate some of the muscles in the hand and the Medical Research Council grading is inclined to be a rough and ready method. It is best, therefore, to assess the function of the hand in certain activities, such as opposition of the thumb, flexion of the fingers, various types of grip, and the ability to carry out crafts without using trick movement To this end careful supervision in the occupational therapy workshops is of great value

Regular measurement of the grip, using a dynamometer, should be made and a quantitative estimate of the progress in various activities is most helpful to the examiner and encouraging to the patient, as, for example, the ability to play the piano for increasing periods, or to increase production in whatever crafts the patient is performing

The correct methods of examination for the muscles of the hand have been discussed in Chapter 1, but there are certain trick movements which can confuse the examiner into believing that there is contraction in some muscles when, in fact, there is not These will now be discussed as they apply to each nerve injury

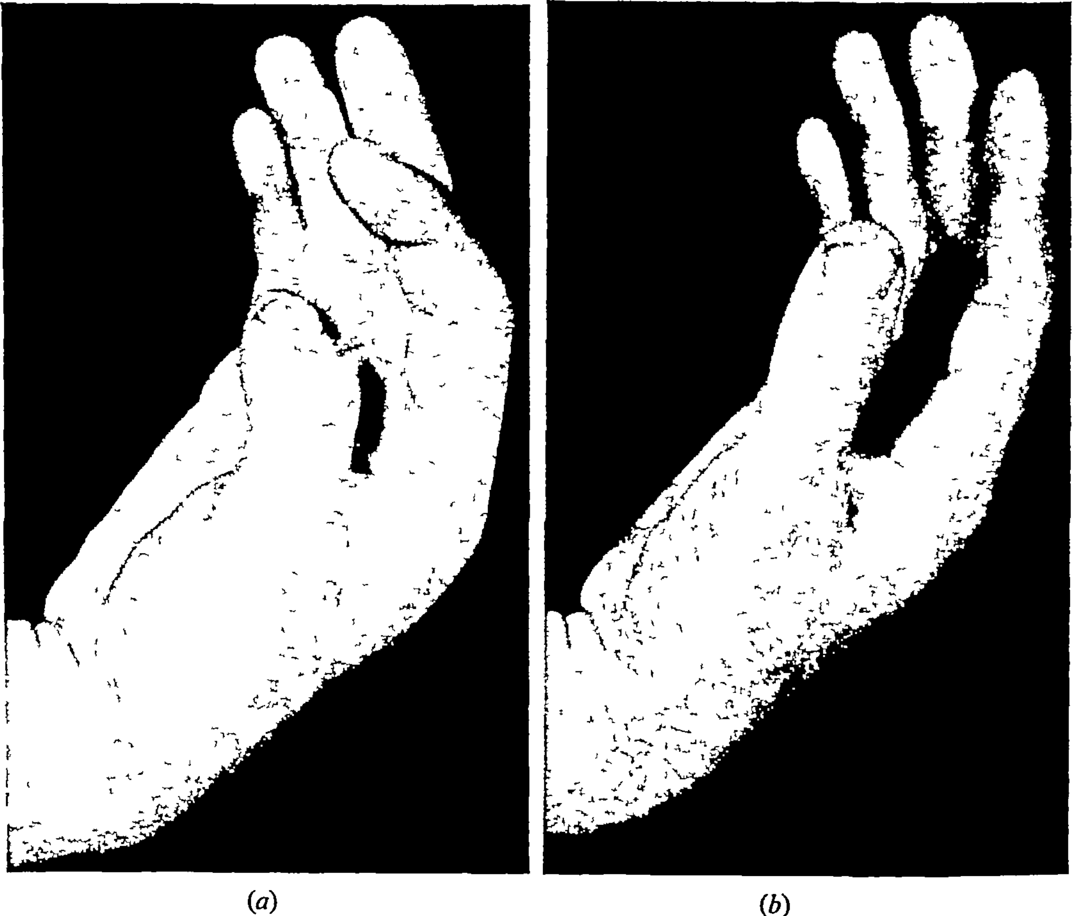
Radial nerve palsies

In radial nerve palsies the wrist extensors are paralysed, but relaxation of the wrist flexors can give the impression of an extensor action

To be certain that there is no action in the wrist flexors, the patient's wrist should be supported in full dorsiflexion, and the tendons felt at the back of the wrist while the patient is asked to try to dorsiflex In the absence of any action in the wrist extensors the wrist will be felt to flex instead of extend. In the early stages of recovery of the wrist extensors the patient will be unable to institute dorsiflexion of the wrist even when thus examined If the patient is asked to grip an object, however, a flicker is often felt in the wrist extensors, this is because a muscle contraction is more easily detected in the early stages of recovery when it acts as a synergist rather than as a prime-mover Again, a sign of early recovery is apparent when the patient is asked to dorsiflex the wrist in the inner range, he no longer flexes first—that is, the lack of trick movement is an indication of recovery even though the prime-mover action may not be obvious The extensors of the metacarpo-phalangeal joints are paralysed, but extension of the fingers is possible because this is performed by the interossei If the patient is asked to extend the metacarpo-phalangeal joints, flexion will be seen at these joints, as the lumbricals contract in an effort to produce extension When the metacarpo-phalangeal joints are supported in almost full extension and the patient is asked to extend the fingers, hyperextension of the interphalangeal joints will be seen as the interossei attempt to trick the movements, and at the same time the metacarpo-phalangeal joints will flex

The earliest sign of recovery in the extensor digitorum is the lack of flexion at the metacarpo-phalangeal joints rather than the obvious prime-mover action

Extension of the terminal joints of the thumb is possible in all patients with a radial nerve palsy because the short abductor always, and the short flexor sometimes, have an insertion into the extensor expansion When the patient is asked to extend the interphalangeal joint of the thumb, the thumb goes immediately into palmar abduction, due to the short abductor action (Fig 24 *a* and *b*) To



(*a*) (*b*)

FIG 24 —*Extension of interphalangeal joint of thumb in radial nerve palsy by the action of the abductor pollicis brevis which can be seen contracting, bringing the thumb into palmar abduction* (a) *Starting position* (b) *Extension of interphalangeal joint of thumbs—note abduction*

demonstrate that this is a trick action, the patient's thumb should be kept against the index finger and prevented from abducting Extension of the interphalangeal joint will then be impossible

An early sign of re-innervation of the extensor pollicis longus is the lack of abduction when the patient attempts to extend the thumb, even though there may not be prime-mover action

Extensor carpi radialis longus —This is the first extensor muscle to recover in a radial nerve palsy, so that attempted dorsiflexion results in radial deviation as the extensor carpi ulnaris is still paralysed and cannot, therefore, exert its action to bring

the wrist into neutral dorsiflexion The early sign of recovery in extensor carpi ulnaris is therefore a lessening of radial deviation when the wrist is dorsiflexed

Median nerve paralysis

It was shown in Chapter 1 that opposition of the thumb to the fingers involves four separate movements—palmar abduction, flexion, rotation and adduction In median nerve lesions at the wrist the palmar abduction is lost but radial abduction is present through the action of abductor pollicis longus Flexion is present, of course, by the long flexor, but rotation is lost Adduction is possible through the adductor (supplied by the ulnar nerve), consequently, when the patient is asked to oppose his thumb to the little finger, the thumb first goes into radial abduction, but as the long flexor brings the thumb across the palm, the thumb collapses into the palm through lack of palmar abduction If the short flexor has no ulnar supply, then the interphalangeal joint of the thumb is flexed by the flexor pollicis longus in an attempt to carry the thumb across the palm, the adductor keeps the thumb well into the palm (Fig 25)



FIG 25—*Attempted opposition of the thumb to the little finger in a combined median and ulnar nerve palsy Note the trick action of the flexor pollicis longus and the inability of the fifth metacarpal joint to elevate*

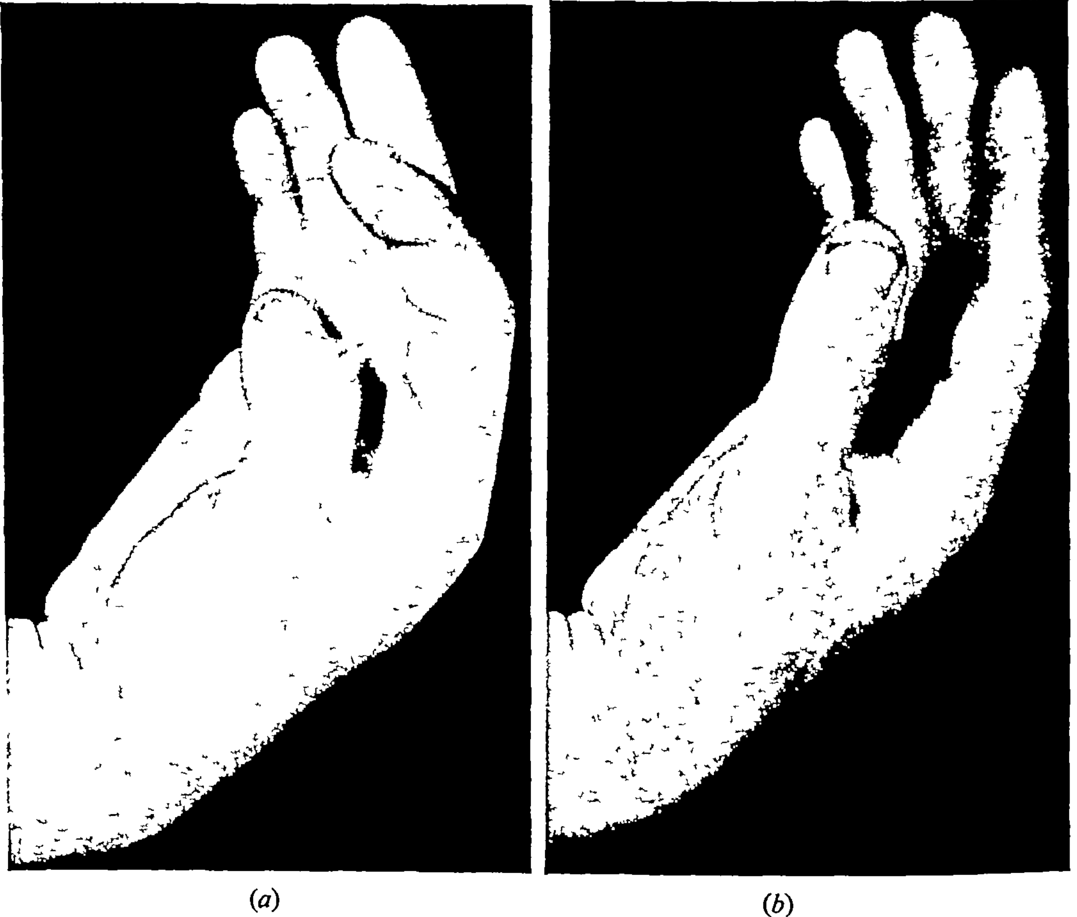
The basis of the lively splint in median nerve paralysis is to put the thumb into abduction and use the combined flexion and adduction action of flexor pollicis longus and adductor pollicis to simulate opposition

The paralysis of the first two lumbricals means that when the patient attempts to bend the metacarpo-phalangeal joints, the interphalangeal joints are hyperflexed, thus attempting to use the long flexor action at the metacarpo-phalangeal joints If the patient is asked to flex the metacarpo-phalangeal joints but keep the interphalangeal joints extended, he will be unable to do so

The first sign of recovery in a median nerve lesion at the wrist is the ability of the patient to rotate the thumb This should be tested in the inner range by supporting the thumb in palmar abduction and slight flexion

The earliest sign of recovery in the extensor digitorum is the lack of flexion at the metacarpo-phalangeal joints rather than the obvious prime-mover action

Extension of the terminal joints of the thumb is possible in all patients with a radial nerve palsy because the short abductor always, and the short flexor sometimes, have an insertion into the extensor expansion When the patient is asked to extend the interphalangeal joint of the thumb, the thumb goes immediately into palmar abduction, due to the short abductor action (Fig 24 *a* and *b*) To



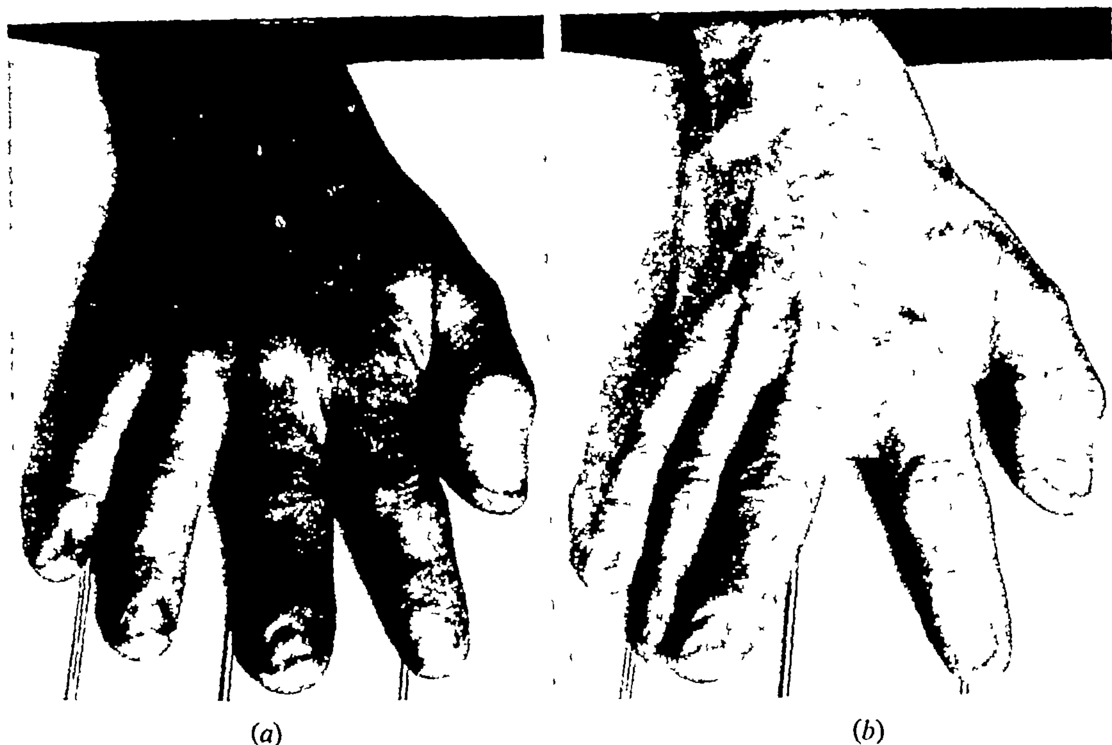
(*a*) (*b*)

FIG 24 —*Extension of interphalangeal joint of thumb in radial nerve palsy by the action of the abductor pollicis brevis which can be seen contracting, bringing the thumb into palmar abduction* (a) *Starting position* (b) *Extension of interphalangeal joint of thumbs—note abduction*

demonstrate that this is a trick action, the patient's thumb should be kept against the index finger and prevented from abducting Extension of the interphalangeal joint will then be impossible

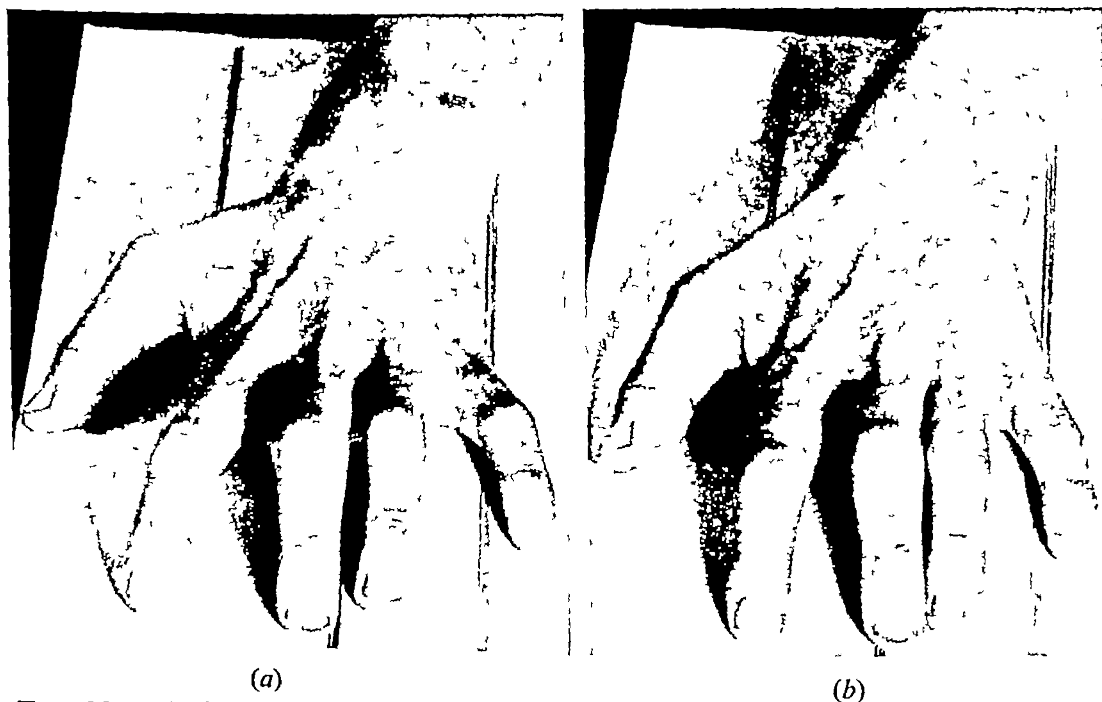
An early sign of re-innervation of the extensor pollicis longus is the lack of abduction when the patient attempts to extend the thumb, even though there may not be prime-mover action

Extensor carpi radialis longus—This is the first extensor muscle to recover in a radial nerve palsy, so that attempted dorsiflexion results in radial deviation as the extensor carpi ulnaris is still paralysed and cannot, therefore, exert its action to bring



(*a*) (*b*)

FIG 27 —*Normal abduction of fingers* (a) *Middle finger raised off the table* (b) *Middle finger abducted to the ring finger—note that the wrist has not moved Compare the relation of the ulnar border of the wrist to the double ruled lines on the paper*



(*a*) (*b*)

FIG 28 —*Trick movement in abduction of the fingers in ulnar paralysis—note the wasting in the interosseus spaces* (a) *Middle finger raised off the table* (b) *Patient attempting to abduct towards the ring finger Note the movement of the wrist that has occurred, compare the relation of the ulnar border of the wrist to the double ruled lines on the paper in each case*

Ulnar nerve paralysis

The paralysis of the interossei means that the interphalangeal joints cannot be extended unless the metacarpo-phalangeal joints are supported so that the long extensor can act on these joints Without the metacarpo-phalangeal joints supported, it will be seen that the patient can only extend the interphalangeal joints by extending the metacarpo-phalangeal joints as well This is the principle of the lively splint which supports the metacarpo-phalangeal joints, thus allowing the long extensor to act on the interphalangeal joints

The paralysis of the interossei also means that abduction of the fingers is seriously hampered However, the long extensor can easily trick this action This is particularly noticeable in the index and little fingers which each have an extensor of their own as well as a tendon from the extensor digitorum communis Adduction can be tricked by relaxation of the extensors and by contraction of the long flexors

When the patient tries to abduct the fingers in an ulnar nerve palsy, the long extensor tendons can be seen to stand out on the back of the hand, and the metacarpo-phalangeal joints go into extension (Fig 26) Similarly, in adduction, the metacarpo-phalangeal joints can be seen to go into slight flexion To emphasize this trick movement the patient should place the hand palm down on the table and be asked to lift the middle finger off the table This involves the long extensor

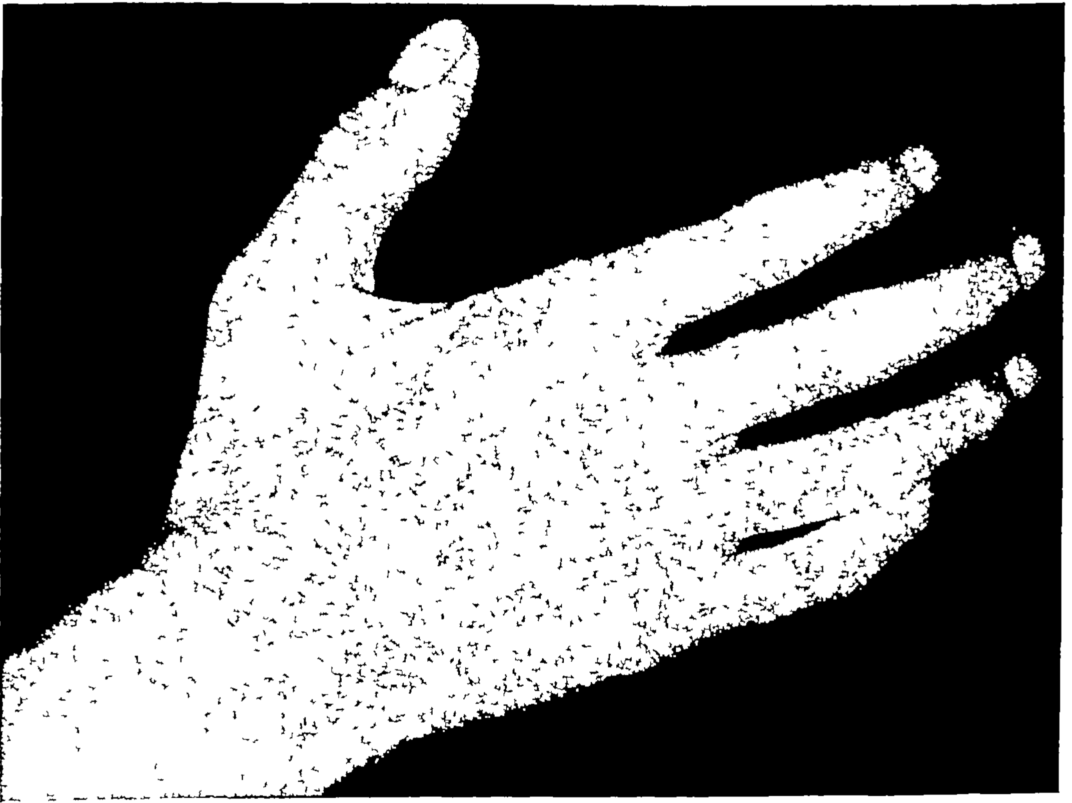


FIG 26—*Trick abduction of the fingers in ulnar nerve palsy*

tendon in maintaining the finger in the air against gravity, and it is now no longer free to act as an abductor The patient is now asked to move the finger from side to side, when it will be found that it is impossible for him to do so Instead, the

results in a characteristic posture of the little finger in opposition of the thumb to that finger Normally, when one opposes the thumb to the little finger, the fourth lumbrical supports the metacarpo-phalangeal joint in slight flexion and the proximal interphalangeal joint is usually extended by the interossei In ulnar paralysis, attempts to oppose the little finger result in acute flexion at both interphalangeal joints (Fig 25) The fifth metacarpal is depressed instead of being elevated

In ulnar nerve paralysis the patient is unable to maintain a pinch with the thumb against the index finger and make a good "O" This is due to the paralysis of the adductor

The early signs of recovery in the ulnar supplied muscles are as follow The first muscle to recover after a lesion at the wrist will be the abductor digiti minimi, contraction in this muscle is best looked for when the patient opposes the thumb to the little finger—a flicker is invariably seen in this circumstance before the prime-mover action is detected

As recovery proceeds in many patients the fifth finger becomes progressively abducted

The first sign, clinically, of recovery in the interossei is the absence of the trick movement in abduction When the patient raises the middle finger off the table and attempts to move it from side to side, there may not be actual movement of the finger, but the trick action of the lateral movement of the palm and wrist is not seen This indicates that the interossei are beginning to work If the interosseus spaces are carefully observed, a little flicker can be seen but the finger itself remains absolutely still The only way to decide whether the interosseus is working or not is by asking the patient to move the finger when the palm is flat on the table and the fingers raised off it by the long extensors Any other method, including testing the ability to hold a piece of paper between the fingers, is not sufficiently reliable

The clinical signs of recovery in the adductor of the thumb are very difficult to detect, therefore the earliest sign of recovery in this muscle is best seen by the absence of trick movement so that adduction without flexion of the interphalangeal joint or hyperextension of the metacarpo-phalangeal joint indicates that the adductor is working

Recovery in the lumbricals is shown by the ability of the patient to flex the metacarpo-phalangeal joint with the interphalangeal joint extended, and as soon as these muscles begin to work the power of grip increases rapidly

Assessment of sensation

Testing

The response to cotton-wool, pinprick and hot and cold are all used to assess the extent of sensory loss and test recovery

Two points need special emphasis

(1) In the early stages after nerve section, the area of sensory loss diminishes slightly as neighbouring nerves take over its function

(2) The most reliable way of getting an accurate idea of the area of sensory loss is to ask the patient to map out the area with the index finger of the other hand

So many of the tests for sensation such as two-point discrimination depend on judgment, concentration and even intelligence, results, therefore, are not always consistent Whenever examining for the extent of sensory loss, the patient should be asked to map out the insensitive area before any other tests are carried out

whole palm and wrist joint are seen to move from side to side in a quite characteristic fashion (Figs 27 *a* and *b*, 28 *a* and *b*) This sign is absolutely consistent and is to be seen in all cases of interosseus paralysis The sign is positive for the ring finger as well It is not advisable to use it for the index and little fingers as they have two extensors, and one can support the metacarpo-phalangeal joint in extension while the other produces some trick abduction

The paralysis of the adductor means that true adduction of the thumb to the index finger is difficult It is still possible, of course, to obtain a combination of relaxation of the abductors and, most important of all, gravity to bring the thumb down to the index finger If, however, the patient is asked to bring the thumb to the index finger with the radial border of the hand facing directly downwards, he cannot adduct the thumb against gravity without flexing the interphalangeal joint of the thumb At the same time the long extensor can be seen to be contracting vigorously so that these two muscles are effective adductors They are, however, unable to adduct the thumb against any degree of resistance With the thumb fully adducted, the patient is asked to try to adduct against gravity and against the slight resistance of, say, a pencil, immediately the interphalangeal joint of the thumb goes into very acute flexion (Fig 29) In many patients this attempted

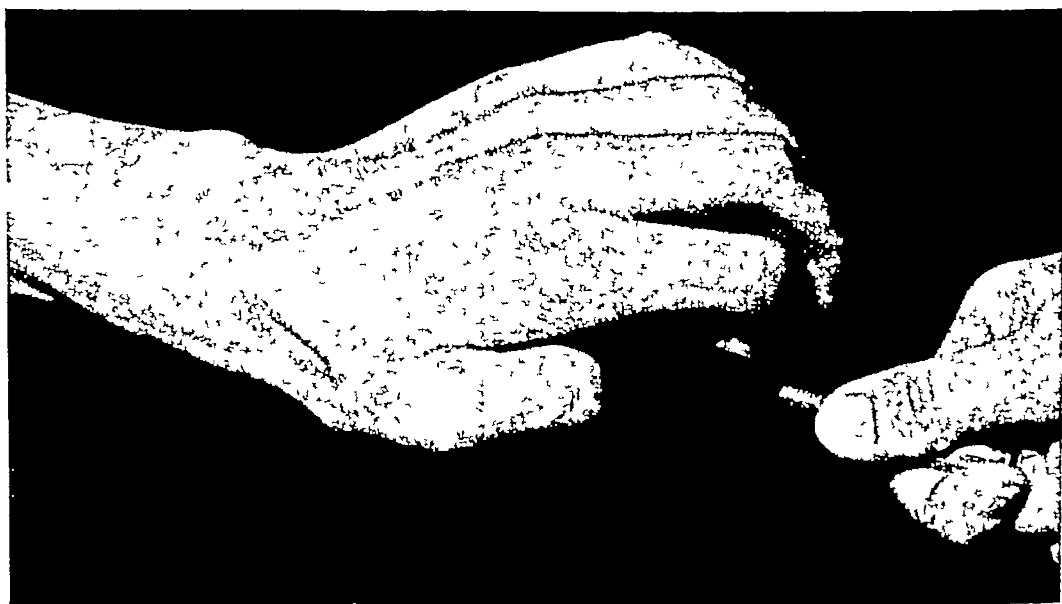


FIG 29—*Trick adduction of the thumb in ulnar palsy Note the action of the flexor and extensor pollicis longus*

adduction of the thumb with gravity resisting shows trick action of the long extensor as the interphalangeal joint is flexed In a few patients the long extensor performs this trick action entirely and no flexion at the interphalangeal joint is seen at all In these circumstances the metacarpo-phalangeal joint of the thumb goes into hyperextension and the characteristic sign of this trick movement is the pushing of the thenar eminence across the palm

The paralysis of the third and fourth lumbricals means that when the patient attempts to flex the metacarpo-phalangeal joint he cannot do so without acute flexion of the interphalangeal joints The paralysis of the hypothenar muscles

breaks down the insulation of nerve fibres and an artificial synapse is formed between sympathetic fibres and the afferent sensory fibres

SURGICAL TREATMENT

A complete lesion of a nerve, that is, neurotmesis, must be sutured There is not complete agreement among surgeons as to the essential indications for primary and secondary suture In general, however, the common practice is to delay nerve suture for 3 weeks after injury unless the wound is clean, soft-tissue damage is minimal, and the best conditions for nerve suture are available

PHYSIOTHERAPY

Rehabilitation of peripheral nerve injuries can be divided into two stages (1) treatment during the stage of paralysis, and (2) treatment during the recovery stage

The principles of treatment during the stage of paralysis are as follow

(1) The prevention of deformity by splintage
(2) The encouragement of function
(3) The maintenance of full passive range in the joints
(4) The maintenance of good circulation
(5) The re-education of function in any tendons involved with the injury
(6) The prevention of muscle atrophy as much as possible by electrical stimulation
(7) The maintenance of general function of the limb
(8) The constant encouragement of function in the fingers

The treatment of each type of nerve injury will now be described in detail both during the stage of paralysis and during recovery of function

General Principles of Physiotherapy

The patients who have had suture of the median or ulnar nerves will generally have a severe flexion deformity of the wrist when they commence active rehabilitation 3–4 weeks after suture This is because the wrist must be acutely flexed to allow approximation of the nerve ends There will often be a tough scar and a variable amount of oedema on the dorsum of the hand which, if severe, may spread up the arm

The following general principles apply to all nerve injuries, though the remarks concerning the scar will not, of course, apply to closed nerve injuries

Oedema

To control oedema the patient should be seated in the physiotherapy department with the arm resting against a pillow, the elbow as straight as possible, and the forearm and hand in elevation Effleurage is given to dispel the oedema, followed by general exercises, still in elevation, stroking massage is carried down to the elbow If the oedema is generalized the arm should be put in full elevation and the massage given down to the shoulder In the early stages this treatment is given for half an hour twice a day When the patient is undergoing active treatment he should wear a sling with the hand well up over the opposite shoulder, this

Tinel's sign is the classical way of assessing the progressive regeneration of a peripheral nerve The test has become rather denigrated in recent years, but in our experience if it is performed carefully, in most cases it is reliable

The tapping should start distally and work up proximally The limb must be supported carefully so that the tapping does not jar and thus cause a false positive result, and both the proximal and distal sites where the response is obtained must be noted

Henderson (1948) carried out the most extensive analysis of Tinel's sign yet reported He pointed out that if the sign was strongly positive at the site of injury but persistently absent distally, there was no regeneration If strongly positive at the level of injury, but weak distally, there was poor regeneration The best evidence of recovery was when the sign was strongly positive at the site of injury but gradually diminished as the degree of response at the distal site increased Our results bear out Henderson's findings completely In a few cases it was found that the slightest tapping anywhere produced tingling and thus the sign was of no value, but in the great majority of patients it has been found that the Tinel sign is most reliable and well worth performing carefully

The regular performance of sweat tests for assessing sympathetic recovery does not add any information to that obtained by the motor and sensory tests already described Some workers like to use it in children, and though we have no experience of this, we feel that it would be a sound indication for its use Recovery of sympathetic function is seen by the presence of sweating, and the patient notices that the hand does not respond so violently to changes in temperature

It is surprising how often patients predict recovery both in the motor and sensory nerves by stating that they feel recovery is about to occur Many patients have said that they feel as if a muscle was about to function even though there was no clinical sign, and almost invariably they were right

Causalgia

Causalgia is the name given to severe burning pain that occasionally complicates nerve lesions it is associated particularly with partial lesions of the brachial plexus and with median nerve lesions Characteristically, the pain occurs quite spontaneously, is peculiarly intense and may radiate over a wide area of the limb Like trigeminal neuralgia, the slightest physical stimuli, or noise, such as the closing of a door, the sudden draught from a window, or somebody coughing close by, precipitates a recrudescence of the pain The patient characteristically spares his arm by protecting it and commonly keeps it wet to alleviate the pain

Causalgia is a rare complication of nerve lesions In the few cases that we have seen, the pain tends to improve slowly over a long period of time Simple analgesics should be tried at the start, for example, tabs codeine co 2 every 4 hours If this fails 25 milligrams of Largactil three times a day as well is often successful, though it takes a few days on this treatment before the pain begins to lessen If the pain is still severe, sympathectomy is said to be the only treatment of any avail and is done if infiltration of the second thoracic ganglion and the stellate ganglion relieves the symptoms Brooks (1952b), however, has found sympathectomy of no value

The possible causes of this condition are discussed in detail in the Medical Research Council report on peripheral nerve injuries The theory is that injury

breaks down the insulation of nerve fibres and an artificial synapse is formed between sympathetic fibres and the afferent sensory fibres

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allows drainage and prevents oedema from organizing into fibrosis The bandage which is applied between treatments should stop short of the metacarpo-phalangeal joints so as to allow finger movements It should be carried up to the elbow, care being taken to ensure that there are no gaps in the folds of the bandages which would allow oedema to bulge through If a splint, such as a cock-up splint in a radial palsy, is being worn there must be a supporting bandage to keep the splint on to the arm The patient is encouraged to exercise the fingers by bending and stretching them whilst in the sling

Skin condition

The skin in both a median nerve and ulnar nerve lesion is dry, scaly and, of course, anaesthetic To improve the skin condition, olive oil massage is given twice a day Oil should be massaged around the nail beds which are inclined to collect debris Heat helps to improve the skin condition, relaxes any muscle spasm, and encourages the patient to move his fingers It is essential that whatever form of heat is used it should not be more than pleasantly warm, to avoid the risk of burns If a scar has healed, wax is the best form of heat and can be used in elevation if there is much oedema, if the scar is not healed, warm saline solution soaks are used When the wound is oozing and infected, radiant heat is given at a distance of not less than 18 inches If the scar is bound down, frictional massage around it is given with the thumb and finger, using olive oil In slight degrees of adherence this is given twice a day, but when the scar is very tough the massage is given 4 times a day Following massage each joint is put through a full range of passive movement The physiotherapist supports the finger above and below each joint and moves the joint with her fingers on either side of it The metacarpo-phalangeal joints should be in slight flexion when giving passive movement to the interphalangeal joints For the metacarpo-phalangeal joints, rotation must be given as well as flexion and extension, followed by up and down movement between the heads of the metacarpals and stretching of the webs by passively abducting and adducting the fingers At the wrist joint, apart from flexion and extension, passive ulnar and radial deviation is given, for if this is limited full range of flexion and extension will not be possible Apart from the usual movements in the thumb, passive therapy should continue with full range of circumduction Finally, with the wrist in extension all the fingers should be stretched together, with the metacarpo-phalangeal and interphalangeal joints extended This manoeuvre is not given for 6 weeks after suture so as not to stretch the growing nerve

Re-education

All patients with neurotmesis require re-education of muscle function Although, theoretically, patients with axonotmesis should not require re-education, it is advisable to give some re-education, since many patients will have forgotten how to use their muscles

Patients with inhibition of the quadriceps after patellectomy or meniscectomy require re-education, and in like fashion, patients with axonotmesis often do so

The affected muscle should be supported in the inner range and the patient asked to perform a static contraction The physiotherapist then demonstrates the movement 3 or 4 times and the patient is then asked to perform the same movement himself It is most helpful in the early stages of re-education to coax

the muscle into action by asking the patient to perform the movement in which the muscle is active as a synergist The movement should be demonstrated first on the normal hand if possible The physiotherapist also shows the patient the path of the muscle fibres, what the muscle is expected to do when it contracts, then instructs him to feel for contraction at the muscle origin and insertion The object throughout is to encourage the patient to take an intelligent interest in his own muscle function

The antagonists are often severely weakened and these must also be re-educated In a combined median and ulnar nerve palsy, the wrist extensors are often very weak Throughout treatment the co-ordination of movement must be stressed The muscle should be supported first in its inner range, and, as power improves, the excursion made by the muscle is required to increase until it is acting throughout the full range

Even when all muscles are paralysed for the first few months after a lesion, the patient should be encouraged to use whatever muscles are available and, as previously discussed, lively splints are designed with this end in view Most patients tend to spare and neglect their hand They have learnt to do many things with their unaffected hand and they must therefore relearn how to use the affected hand

Advice on precautions

The anaesthetic hand is extremely liable to be burnt or scalded The less intelligent the patient, the greater are the chances that he will develop a burn somewhere during the stage of paralysis The chief dangers in burns are from cigarettes and radiators, and hot water in the case of scalds Trophic ulcers are liable to occur from activities such as carpentry The patient must learn how to use his eyesight to compensate for his paralysis He must be warned repeatedly about the dangers of burns and scalds and develop a consciousness of them Warm water should always be tested first with the normal hand The patient should not lift a hot cup of tea with the affected hand, and he should always wear a glove, even in summer In cold weather there is danger of the hand stiffening, and to prevent this the patient should have a warm water soak for 5 minutes 2–3 times a day At night he should wear a glove to prevent him catching his hand on any metal part of the bed, or accidentally touching a hot-water bottle The physiotherapist should cut the patient's nails as they are ridged and hard, patients so often damage the skin when cutting their own nails These precautions cannot be stressed too often

Electrical stimulation

In general, patients with paralysed muscles receive electrotherapy twice daily provided that there is a reasonable chance of re-innervation before the onset of fibrosis The indications and rationale of electrotherapy are discussed in detail in Chapter 8 The skin should be cleaned by washing with soap and water If it is especially hairy, the end of the active disc electrodes should be soaped, preparatory heat is given for 10 minutes, and any open areas covered with Vaseline The longitudinal reaction is preferred for all hand and forearm muscles The physiotherapist should experiment until the best possible position for stimulation is found Each muscle should undergo stimulation for 5 minutes twice a day The pulse duration and output used should be those that give the most comfortable treatment with the minimum output Most patients find that a progressive type

of current is the most comfortable It is a pronounced advantage to use a stimulator that allows the use of variable pulse durations so that the optimum pulse duration for each particular patient can be found

A therapeutic contraction is used; this means that the muscle should be made to contract against gravity After 2 or 3 minutes of treatment, response tends to lessen and the output must be increased Most patients find it encouraging to see their muscles working, particularly in the early stages of treatment, and for this reason alone electrical stimulation has a great psychological value The muscle should be supported so that it works in the inner range, and it is particularly important that the patient should be as relaxed as possible during treatment As the patient is having treatment every day it is most important to avoid erythematous reactions, these can be so pronounced as to make further treatment impossible Consequently, the use of a balanced pulse stimulator is advised This is a stimulator in which a low current of opposite sign is passed during the rest phases (*see* Chapter 8) Talcum powder is applied after every treatment to the skin

For forearm muscles the diameter of the electrodes should be ½ inch, for the intrinsics ¼ inch or less As soon as there is a useful range of voluntary movement electrotherapy should cease

Radial nerve palsies

During the stage of paralysis the feeling of movement should be kept going by passive movements with the forearm in the mid-prone position and the ulnar aspect of the hand on the bench The physiotherapist should support the patient's wrist in extension and ask him to squeeze and grip her hand The physiotherapist grips the patient's hand in such a way that the thumb is in the rotated position, next the fingers are flexed at each joint Finally, the patient is asked to hold his fingers in full flexion and opposition against resistance During the early stages of recovery each muscle is individually re-educated as described below

Brachio-radialis

The forearm is placed in the mid-prone position and the patient is asked to lift the wrist off the table, when the brachio-radialis acts synergically The patient is then asked to flex the elbow with the forearm in the mid position in the inner range, at first without and later with resistance As recovery occurs the range is increased

Extensor carpi radialis and brevis

Both these muscles are retrained as synergists in the early stages of recovery, and there are two methods of doing this First, the patient is asked to deviate the wrist in a radial direction, with support from the physiotherapist At the extreme of movement the patient holds the wrist deviated and tries to prevent the physiotherapist taking the wrist in an ulnar direction With the hand in radial deviation and the wrist supported the patient is asked to hold the wrist in extension The grip involves the synergistic action of the wrist extensors, and thus all forms of gripping are useful

Secondly, the action of these muscles as prime movers is trained by supporting the wrist in full extension and asking the patient to make a static contraction As recovery progresses, their action is trained in successively greater ranges of movement

The muscles are trained as assistants in adduction and abduction of the thumb They can be seen to act when the physiotherapist grips the patient's hand

Extensor carpi ulnaris as a synergist

The patient deviates the wrist in an ulnar direction and holds it against the physiotherapist's resistance at the extreme of movement

The little finger is flexed at the interphalangeal joints and then the patient abducts the little finger This causes contraction in the extensor carpi ulnaris

A third synergistic action is again in all forms of grip

The muscle is trained as a prime mover in extension of the wrist as described for the extensor carpi radialis longus

Extensor digitorum communis

The wrist is supported palm down on the table, with the interphalangeal joints fully flexed, the patient then attempts to extend the metacarpo-phalangeal joints The patient should be shown the movement by the physiotherapist, who should demonstrate it passively 3 or 4 times, and then the exercise is carried out with assistance in the inner range, and then without assistance, and finally through the full range with resistance The patient can see the extensor tendons standing out in this exercise, and his attention should be directed to this As the power of the extensors increases, the patient extends the proximal interphalangeal joints as well Next the hand is supported in extension with the other hand and the fingers raised up in the air Resistance is given first over the proximal phalanx, then over the middle phalanx, and finally over the distal phalanx, thus increasing the leverage as recovery progresses The synergic action is trained by re-educating abduction and adduction of the fingers, at first freely, and then with increasing resistance When the power has returned to a considerable extent, abduction and adduction are performed with each finger in turn raised off the table This, however, is only possible when the extensors are fairly strong

Extension at the metacarpo-phalangeal joint, proximal interphalangeal joint and finally the terminal interphalangeal joint is trained in turn from full flexion, ending up with a full spread of the fingers Patients are encouraged to give resistance with their other fingers and to give increasing resistance

The intrinsic muscles, the lumbricals and the interossei must be re-educated as they work with the extensor digitorum and are invariably weak All forms of games, such as bandage rolling, tiddleywinks and coin games as described in Chapter 2 are suitable

Bouncing tennis balls and gripping sticks, starting with fairly thick sticks, becoming thinner as recovery progresses, all forms of card games and activities such as shuffling and dealing the cards, and making cardboard boxes, are excellent for extensor digitorum function Miming the action for musical instruments to a gramophone record, conjuring and piano playing are other excellent activities for the extensors

Extensor pollicis longus and extensor pollicis brevis

The synergist action is best trained when the interphalangeal joint of the thumb is flexed and the metacarpo-phalangeal joint extended and adducted against the physiotherapist's thumb The interphalangeal joint is then extended, first without and later with resistance

An " O " grip is made between the thumb and each finger in turn and the physiotherapist attempts to pull her finger through Successively bigger objects are then held between the fingers and the thumb

The prime-mover action is trained by supporting the thumb in the neutral position (forearm in the mid position) with the ulnar border of the hand on the table (Fig 30) The thumb is extended at the carpo-metacarpal joint, then the

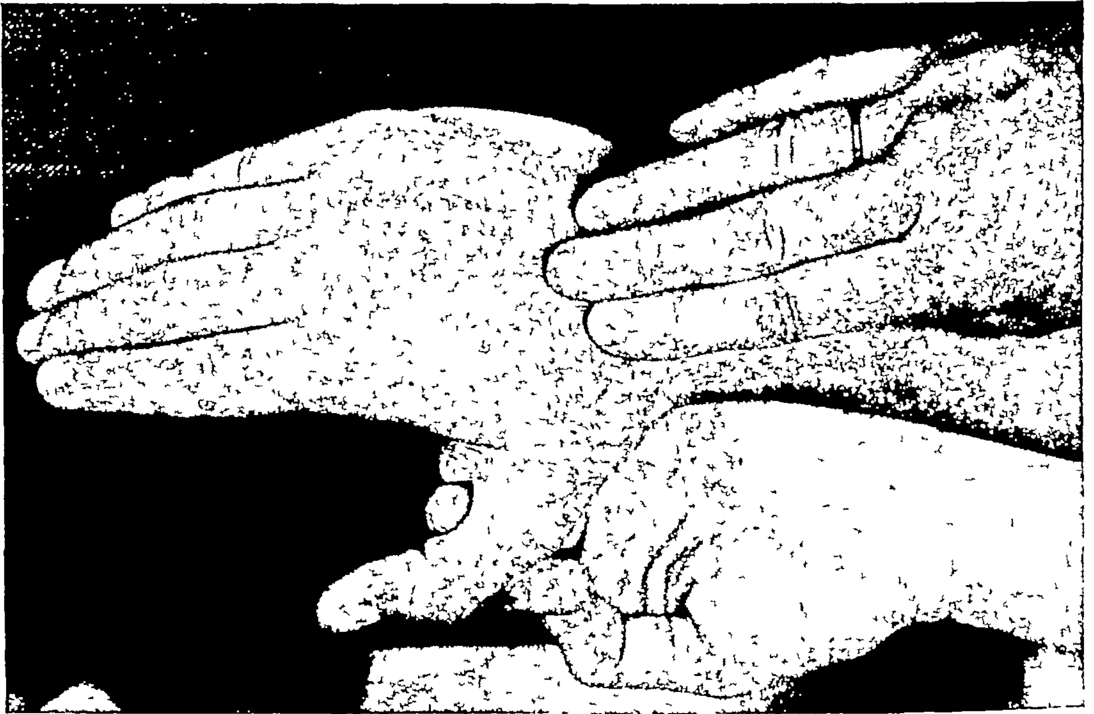


FIG 30 —*Early re-education of extensor pollicis longus*

metacarpo-phalangeal joint, and finally the interphalangeal joint, at first without and then with increasing resistance Exactly the same exercise is carried out with the emphasis on abducting the thumb

All types of games as described in the section on extensor tendons of the thumb in Chapter 2 are appropriate, particularly those involving flicking movements

Abductor pollicis longus

The patient and the physiotherapist grip each others hand, thumb-to-thumb, in this manner the physiotherapist can feel the tendon contracting Increasing resistance is given as recovery occurs

Synergist action is trained in two ways First, whenever the extensor carpi ulnaris and extensor carpi radialis longus contract, the abductor pollicis longus automatically contracts with them Thus, exercises in ulnar and radial deviation and wrist extension are appropriate Secondly, the long abductor works with the long extensor, hence all exercises appropriate for the long extensor are used

With the dorsum of the palm on the table, the muscle is trained as a prime mover in radial abduction, at first in the inner range without resistance and progressing to a full range against resistance

All the extensors of the fingers, the thumb and the wrist are used for the following exercise The patient is made to raise his hand with the fingers and thumb

extended off the table without flexing any of the joints and to hold it parallel to the ground As recovery occurs, this is done against resistance

Ulnar nerve lesions

If the lesion is a high one, the flexor carpi ulnaris and the flexor digitorum profundus to the ring and little fingers will be affected, consequently, these muscles must be re-educated The treatment for the flexor profundus is discussed in detail in Chapter 2 The flexor carpi ulnaris is trained first as a synergist in ulnar deviation and then as a prime mover in wrist flexion

Hypothenar group

The fingers are flexed and the wrist deviated in an ulnar direction, the patient is encouraged to hold this position while the fourth and fifth metacarpals are supported, the intrinsic muscles being paralysed This encourages the synergic action of the hypothenar muscles Opposition of the thumb to the little finger also involves synergic action of these muscles and increasing resistance can be given by asking the patient to prevent the physiotherapist from pulling her finger through the patient's opposed thumb and little finger A third exercise is carried out with the palm down, when the patient lifts the fourth and fifth metacarpals off the table

The patient holds a stick by flexing his fingers over it with the forearm supinated The physiotherapist then attempts to withdraw the stick from his grasp, the patient trying to prevent her from doing so As recovery occurs so the stick used should be progressively thinner

Each muscle is trained in its prime-mover action of flexion, opposition and abduction, starting in the inner range without resistance and progressing to full range with resistance

Adductor pollicis

The patient supports the hands in the prayer position and the thumb is rolled in towards the index finger

A roll of gauze is placed under the thumb between the index finger and thumb in adduction The patient tries to hold this against the physiotherapist's attempt to withdraw it Later, progressively thinner objects can be introduced until a ruler is used The patient must hold the thumb and index finger straight to prevent trick action of flexor pollicis longus

The muscle acts as a synergist with the flexor pollicis longus, particularly when this muscle is working against strong resistance

The muscle is trained as a prime mover in adducting the thumb up to the index finger against gravity and increasing resistance

Interossei

Abduction and adduction—The patient lifts each finger in turn off the bench with the palm down and attempts to abduct the finger Some resistance on the palm should be given in the early stages as there is an attempt to move the fingers by trick action of radial and ulnar deviation of the wrist The metacarpo-phalangeal joints are then fixed on either side of each finger individually, and the patient tries to raise the finger off the table and then abduct and adduct it At first, assistance must be given, but later the patient may be able to perform the movements without assistance It is not often that patients are able to perform this movement against

much resistance The patient attempts to grip a piece of paper between his fingers and prevents the physiotherapist from withdrawing it In the early stages a thick object such as a padded ruler is used

The patient is also asked to cross one finger over the other in turn

Extension of the interphalangeal joint—The interphalangeal joints are put into flexion by the physiotherapist, and the patient is asked to extend, spreading the fingers right out He should feel the pull of the interossei at the back of the interphalangeal joints

The metacarpo-phalangeal and interphalangeal joints are put into very slight flexion and the patient is asked to extend first the metacarpo-phalangeal joints and then the proximal interphalangeal joints, and lastly, the terminal interphalangeal joints As recovery progresses the metacarpo-phalangeal joints are put into gradually increasing flexion to start the exercise Later, increasing flexion of the proximal interphalangeal joint and finally the terminal interphalangeal joint is used in the starting position

Lumbricals

With the palm down on the table the metacarpo-phalangeal joints are flexed Assistance is given by the physiotherapist by putting her hand round the proximal interphalangeal joints which should, of course, be in extension The patient holds the position with the metacarpo-phalangeal joints at 90 degrees and the interphalangeal joints extended Finally, the physiotherapist provides resistance against extension of the metacarpo-phalangeal joints, the patient being asked to think of lifting up the metacarpal heads The patient then flexes and extends the metacarpo-phalangeal joints against increasing resistance from the physiotherapist

The patient attempts to pull the little and ring metacarpal heads in line with the index and middle fingers, then he tries to flex and extend the fingers at the metacarpo-phalangeal joints

Shadow games are particularly useful for re-education of the lumbricals

Interossei and lumbricals

The following activities are useful for the re-education of co-ordination of both these groups of intrinsic muscles which so often work together

Cupping the hand and trying to make as deep a hollow in the palm as possible and then spreading the fingers out

Opposing the thumb to the fingers in turn against increasing resistance

Spreading the fingers around a ball and then squeezing it

Rolling marbles, moving pennies from the back of one finger to the other, and games with rubber bands (*see* Chapter 2)

Manipulating buttons, lacing shoes, fastening buckles and hooks and eyes

Writing, the handles of the pen or pencil being padded at first fairly thickly, and then, as recovery progresses, reducing the thickness

Picking up small objects such as lentils and pins, one at a time

Training in the recognition of different objects by touch with the eyes shut, such as keys, marbles and knobs

Median nerve lesions

In a high lesion of the median nerve there will be involvement of the wrist and finger flexors, the re-education of these muscles is discussed in detail in Chapter 2.

Thenar muscles

Abductor pollicis brevis —The patient holds the hand in the mid-prone position, with the ulnar border of the hand on the table, and attempts to hold the thumb in palmar abduction As the muscle improves, resistance is given and the movement is executed in an increasing range

The patient is asked to try to crease the thumb At first the thumb is inclined towards the ground and is assisted by gravity Later, it is held in a neutral position and then inclined against gravity and resistance so that the movement is being carried out in full supination Perhaps the most important function of the short abductor is opposition of the thumb The patient is encouraged to bring the thumb across the palm touching each finger in turn He makes an " O " against each finger in turn and the physiotherapist attempts to pull her fingers through

Flexor pollicis brevis —The thumb is held in flexion at the metacarpo-phalangeal joint with the interphalangeal joint extended to prevent trick action of the long flexor The flexion of the metacarpo-phalangeal joint of the thumb is trained, at first in the inner range with the thumb level, with the ring finger, and moving to the little finger, and later, as recovery progresses, in an increasing range until it is carried from well outside the index finger to the little finger

A pen is laid along the line of the short abductor and the patient attempts to roll the thumb over it

Opposition

Opposition is a combination of short flexor, short abductor and opponens action Apart from the exercises already described for the short flexor and abductor, the following exercise for rotation of the metacarpal is used

With the thumb lying in palmar abduction against the index finger the patient is encouraged to rotate the thumb, bringing it across the proximal phalanges so that the nail points vertically upwards A rubber band is useful for all lengths of movement from the index finger to the thumb, the patient pulling across the hand

The opponens is most active in holding the position of extension, whereas the short abductor is most active actually in opposition The extensor of the thumb must be trained, as it is essential for the pinch grip in opposition All forms of grip are also trained

SCHEME OF WORK IN THE OCCUPATIONAL THERAPY DEPARTMENT FOR NERVE LESIONS

It is essential that patients should have physiotherapy treatment before coming to the occupational therapy department

All patients with hand lesions are given sorbo rubber shapes cut to the type of grip it is desired to encourage, and the size of hand They should be egg-shaped if intrinsic action is being developed (small end to little finger), funnel-shaped if power of the long flexors is required They are given to the patient to use on all possible occasions when not actually undergoing treatment

Splints can be made in this department unless there is a splint workshop available within the hospital

Aims of treatment are (1) mobilization of the wrist and fingers, (2) reduction of oedema if present, (3) restoration of lost power of active muscles, (4) correction of deformity with lively splints, when necessary with a night resting splint,

(5) progression when necessary, and strictly under medical direction, to daily serial stretching, and (6) reduction of feeling of inadequacy and fear of future disability by an active and progressive series of work projects within the patient's capacity

Stage of Paralysis

Median nerve lesion

Lively splint

The splint described on page 101 will maintain the correct position up to the point of resistance of the rubber, usually that of writing, sewing, drawing, painting, and light assembly work Beyond this, the thumb will compensate by adduction and flexion of the interphalangeal and metacarpo-phalangeal joint, with corresponding adduction and flexion of the little finger

The aim is gradually to restore the full power of the hand, and it is not considered expedient, therefore, in the light of experience to delay this in order to ensure that the patient does not develop trick movements However, it is important to retain the correct pattern of function built up in the brain This end is achieved by a balance of progressively harder work combined with work of a much lighter type using the thumb in the correct position maintained by the splint and the conscious use of function This should be done under supervision during the whole of the period and at least twice a day Special attention should be given to maintaining abduction and opposition of the little finger These movements are apt to deteriorate as they are the response to opposition of the thumb, or should be, but it is interesting to note that most people do not make full use of this movement, and many are quite unable to oppose the little finger at all It is advisable for some direction to be taken from the uninjured hand However, in cases where only partial recovery of the thenar muscles occurs some compensation can be made for the loss of partial rotation if opposition and abduction of the little finger has been fully maintained or taught

Work usually starts 24 days after suture and should be of a light nature, rhythmical, and involve no static positions, especially if any oedema is present After 5 weeks the work should be harder, aiming at power, but some light work, as already described, must continue

Suggested projects up to 5 weeks are basketry, embroidery, tapestry, wireless construction, Meccano, weaving with netting shuttle, and light leather work For children, bead threading, plasticine, bouncing putty, clay modelling (if the skin is fully healed), brick building, finger painting, glove puppets, card building Games should include draughts, with pucks at least 3 inches in diameter, spillikins, Halma, Chinese Chequers, bagatelle

Drawing, painting and writing are contra-indicated, as although the thumb is used in rotation, it is held statically over too long a period, thus inhibiting circulation and promoting oedema

Work to build up power

Stool seating, lino-printing, pottery, hide leather work, rug weaving, wood carving, willow basketry, and veneering Weaving can be continued so long as a half spherical hand grip, which fits the hand and gives a good resistance, is used

After 7 weeks, work can become really hard woodwork, preferably involving veneering, mild steel shaping, ironing for ladies, using a knitting machine, printing,

games, and draughts with weighted pucks Cross-cut sawing can be started at this stage, but the patients should use both hands, as a second person being involved means that full control over the tool is not possible, and a sudden unexpected jerk can strain joints not under the patient's control It is excellent movement for the whole arm, the shoulder and the hand

Period of recovery

The hand should be strong by this time with the exception of the paralysed group Wrist movement should be free and full, and although strong work should be continued, the main work should be directed to re-education of the recovering group Less time is given to regaining power of the unaffected muscles and more to the weak group Not until the muscles have control of the full range of movement should lively splints be discontinued, if the patient is working alone Splints can be discarded if manual assistance is given by the therapist for the function performed, for the splint allows the muscles to be used in the inner range

Projects for re-education

These include screwdriving, using the thumb and the tips of the fingers, with round-handled short screwdrivers of the constructional toy type with wooden screws and holes, involving very little resistance, draughts, with progressively heavier weight of the discs, peg games, setting up of printer's type, fastening buttons and tying bows, mosaic work, fly tying, flower making, the setting of diamante jewellery involving the use of tweezers, watch repair (if known), bagatelle, darts (this involves a strong movement and should be reserved for later stages), papier mâché work, pricking out seedlings, bead threading and jewellery chain linking, and paper sculpture

As power recovers, progress can be made to greater resistance, harder screwdriving, darts, painting and drawing, writing, Meccano construction, wood cutting, wood carving and veneering, pottery, knitting, crochet and tatting Most of these tasks involve static contraction

Ulnar nerve lesions

First eight weeks of activity

The aim is to use extensor digitorum communis to achieve interphalangeal extension with the aid of a lively splint and build up the power of the hand The splint is described on page 106

Crafts useful in this respect include sandpapering and planing, papier mâché work, pottery, lino-printing, playing the mouth organ, adaptations to drilling, weaving, and cutting with large dressmaker's scissors

Beneficial games should include draughts with discs of adequate weight and size

A circle is cut out of a piece of plywood large enough for the fingers to pass through only when straight This is placed over a bowl of dried peas and patients compete in trying to pick out the most peas in the shortest time (Fig 31)

Eighth week after suture

Work is graded to build up the power of the hand, the forearm and the shoulder generally Light work is continued for separate short periods to maintain detailed function Crafts used for this stage are carpentry and veneering, rug weaving, stool seating, and willow basketry Useful games are blow football, draughts

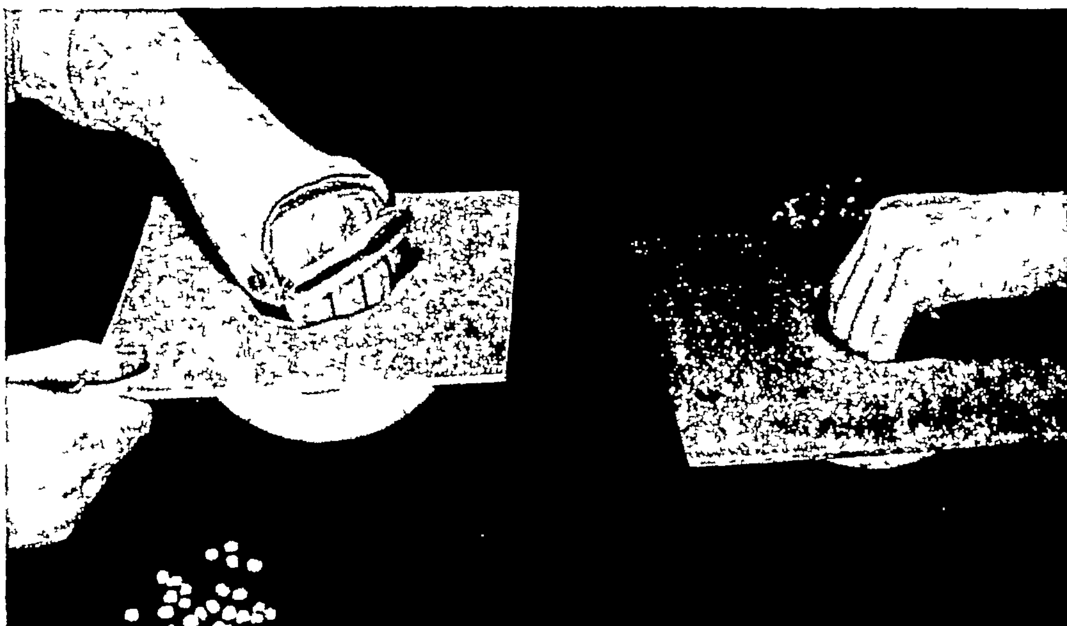


FIG 31 —*Competitive game used for encouraging metacarpo-phalangeal flexion with interphalangeal extension (as, for example, in an ulnar palsy) The holes must be small enough to prevent entry unless the proximal interphalangeal joints are extended and opposed to the thumb*

with weighted discs, and passing the marble Games for children are sandpit work with spade and bucket, pattern tins, finger painting, plasticine fashioning, skittles, " balloon tennis " with a badminton net

Radial nerve lesions

These disabilities are the most liable to cause loss of general muscle power, due to paralysis of the finger extensors

The usual " cock-up " splint prevents full use of the hand and wrist Wearing no splint will prevent full finger flexion

A lively splint is, therefore, essential and is made in such a way that the grasp is interfered with as little as possible (two or three power of springs should be available according to the activities of the hand) The splint is described on page 107 If doing very powerful work the flexors should not be able to overcome the strength of the spring, otherwise the hand will move into wrist flexion as power is increased, but if the powerful spring is maintained in light work or usual daily living activities, active wrist movement will not be maintained

The activities used aim to build up the power of active muscles with the aid of the lively splint Methods are used which involve full abduction of the thumb in order to give extension of its terminal joint

Time is needed to accustom the patient to the lack of balance in the use of the hand, and work should be of a fairly light nature for the first 2 weeks to enable the patient to use the splint as the wrist extensor, otherwise there will be a tendency to flex the wrist first before performing a movement This is very hard to eradicate when the extensor group begins to recover

First three weeks of active work

The following activities are useful during this period basketry, light leather work, light assembly work, setting up of printer's type and block printing, clay modelling, weaving with appropriate adaptation, light wooden toy making, wireless construction, Meccano construction, rug weaving, braid rugs and rug making on an upright loom (gravity helps wrist extension), tapestry (for helping terminal extension of the thumb), greenhouse gardening, and dressmaking

The power of the active muscles can be increased after 3 weeks by using lathe work, metal tapping and hammering, letterpress and block printing, sandpapering, carpentry, veneering and wood carving, sawing, filing, polishing, cement brick making, splint making, and stool seating The following are useful for children weaving, with an adaptation for building up power, bead stringing, sand table, puppetry, bricks, Meccano construction, wooden construction, clay modelling, block printing, and cane work

Re-education

When contraction of the wrist extensors becomes apparent it has been found wise to cut down by half thetime spent on strong activities, and to focus attention on building up the power of the extensors and reforming the correct pattern of movement as recovery proceeds

The trick movement of flexing the wrist to extend the metacarpo-phalangeal joints persists, although when concentrating, the patient can grasp and extend the wrist fairly strongly

Stage of Recovery

Activities should now concentrate on slow movements, giving the patient time to use correct function

As wrist extension recovers first, activities are used which involve finger flexion followed by wrist extension This is provided by drilling on a hand bench drill, draughts, using magnetic discs on a vertical board, furniture painting, stool seating, using a wide shuttle

Once the patient has some power of extension and is using the correct pattern of movement, work can be increased in power within the capacity of the extensors Work which is too strong will only result in over-activity of the wrist flexors and prevent the extensors working in their inner and middle ranges

Metacarpo-phalangeal extension

It will be observed that the metacarpo-phalangeal joints will extend more easily when the fingers are allowed to abduct and remain in slight flexion Advantage should be taken of this in the early days as the patient will have to remember to extend the wrist at the same time as extending the metacarpo-phalangeal joints

Activities

A useful adaptation to weaving is a flat vertical disc made so that the diameter fits the hand with the proximal interphalangeal joints flexed, on to which the patient places the flat of his hand to grasp and turn Draughts with magnetic discs on a vertical board and sandpapering on a block may also be employed

The resistance of materials will sometimes assist metacarpo-phalangeal extension with interphalangeal flexion Extension is used as antagonist to the flexors or

fixators for the intrinsic muscles The following crafts are appropriate clay modelling, potter's wheel, setting up printer's type, plywood cutting on a treadle fret-saw, weighted draughts, pushing discs instead of lifting them, furniture polishing, flip football Table tennis, piano playing, and typing for those familiar with its correct use, and for short periods only, as active use of the wrist is not stressed

Short periods of hard work should continue throughout this stage to maintain the power of the normal muscles Sawing for men and some young women, gardening, hoeing, raking, weeding, edge cutting, and mowing, and pipe bending are all excellent crafts for hard work

ASSESSMENT OF RESULTS OF TREATMENT

Return of function after neurapraxia and in axonotmesis is perfect In this section, therefore, the results of neurotmesis only are discussed In general, our experience has been the same as that of Seddon and Brooks (1954) that the rate of growth of the nerve is between 1 and 2 millimetres a day It has been said that full recovery of independent action of the interossei is rarely seen However, in most cases where full-time treatment throughout the recovery stage was able to be given, a surprisingly high proportion of patients did recover independent intrinsic action

Certainly in the great majority of patients a really useful hand resulted after nerve suture The final result depends chiefly on the complications that can occur, the main ones being associated with tendon injury resulting in adherence, soft-tissue damage resulting in fibrosis, and trophic skin damage due to the sensory loss

The result to the patient depends on to what uses he intends to put the hand The recovery of fine sensation including two-point discrimination is very important in the highly skilled worker

The best assessment for motor and sensory recovery in nerve sutures is that described by Highet (1954)

Motor recovery

For motor recovery the following grades are described

(0) No contraction in any of the muscles supplied by the affected nerve
(1) Perceptible contraction in the proximal muscles
(2) Perceptible contraction in proximal and distal muscles
(3) All muscles act against resistance
(4) All synergic and isolated movements are possible
(5) Complete recovery

Sensory recovery

The following are grades of sensory recovery

(0) No sensation
(1) Deep cutaneous pain in the autonomic zone
(2) Superficial pain and tactile sense in the autonomic zone
(3) As for (2) with the disappearance of over-response
(4) There is also recovery of two-point discrimination within the autonomic zone

Most patients with ulnar nerve sutures obtain grade 3 in sensory recovery and

grade 3 in motor recovery All but 2 of our series obtained grade 2 in sensory and grade 3 in motor recovery in the median nerve All the radial nerve palsies in our series obtained grade 3 and most grade 4 in motor recovery

Function in peripheral nerve injuries continued to improve for a very long time, particularly if the patient used his hand as much as possible

The final result of nerve suture at the wrist should not be assessed for 3 years

The results in each type of nerve injury will now be discussed in detail

In general the factors that influence a good recovery are an absence of complications such as jagged wounds, fibrosis, long delay between injury and suture, long distance for the nerve to travel, the amount of nerve loss and, most important of all, the desire of the patient to get better and work hard

Results in ulnar nerve lesions

The first sign of recovery of an ulnar nerve lesion at the wrist is a flicker in the abductor digiti minimi It has already been shown that this is best seen when the muscle acts synergically when the thumb is opposed to the little finger When the lesion was at the wrist, the average time between nerve suture and the appearance of a flicker was 81 days in our series (extremes, 73–93 days)

When the suture was performed 1 inch above the wrist the average time was 111 days (extremes, 100–120 days) A number of sutures were performed at 1½ inches above the wrist The average time before a flicker was seen was 144 days, but there was a small group in whom the average time was 170 days It will be seen from these figures that the rate of regeneration is roughly 1 inch a month and confirms the general experience Taken in conjunction with the electrical signs, the combination is reliable enough to suggest that if there is no sign of recovery 2 months after it should be expected, something serious is preventing progress

The average time between the appearance of a flicker in the muscle when acting as a synergist and a flicker when acting as prime mover was 3 weeks Forty days later the muscle achieved a grading of 2 on the Medical Research Council scale, and by 60 days after the first appearance of a flicker a grading of 3

The average time before obvious appearance of lumbrical action was 140 days, and for interosseus action between 380 and 400 days These times are at least twice as long in our experience as for axonotmesis

The average time for full function from damage to the nerve at the wrist causing an axonotmesis was 7 months In the case of neurotmesis at 2-year follow-up 40 per cent achieved grade 4 motor and 40 per cent grade 3 motor recovery

Sensation

In the early stages of sensory recovery, the patient described the response to the Von Frey's hair or cotton-wool as a dead feeling A pin feels blunt and stroking evokes a numb sensation

After sensory testing the patient usually complains of pins and needles persisting for some minutes A band of hyperaesthesia at the level of recovering sensation is a characteristic of regeneration, and is due to the late insulation of the nerve by the developing myelin sheath An early sign of sensory recovery is the patient's description of a general feeling that the hand is again a part of him The patients find it very difficult to explain what they mean, but they definitely feel that something is happening in the sensory nerve This may be observed despite there

being no objective evidence of sensory recovery The return of sensation to pinprick is much faster than that for cotton-wool or the Von Frey's hair The average rate of return of sensation to pinprick was found to be 1 inch in 6 weeks, whereas that for cotton-wool or the Von Frey's hair was 1 inch in 3 months

In the early stages of recovery the patients invariably feel tinglings as well as a sensation of touch or pain on testing

It took on an average 6 months from the time of the first reacting to touch sensation to an almost normal response without tingling It was usually 1 year before the sensation was practically indistinguishable from normal Return of temperature sensation was characterized by an extreme feeling of heat or cold on testing with the tuning fork or cold or warm water It takes slightly longer to regain normal temperature sensation than it does normal touch In the cases studied sensation was grade 4 sensory recovery in 25 per cent and grade 3 sensory in 50 per cent at 2-year follow-up

Transposition of the ulnar nerve at the elbow

As the conditions for which this operation was carried out varied so much in different patients, the statistical analysis is not presented It must be emphasized though that as soon as traumatic ulnar neuritis is diagnosed, operation should be advised without delay The results were bad when there had been a delay of months before operation

Results in median nerve lesions

Motor recovery

It is very difficult to judge the presence or absence of a contraction in the flexor pollicis brevis and the opponens unless the short flexor has a complete median supply, but this is unusual Consequently, the only indication before a flicker appears in the short abductor is a general sign that the patient's function with his thumb has improved If, however, complete relaxation of the thumb can be obtained, the medial aspect of the thumb can be seen, with progressive recovery, to lie along the index finger and an increasing distance from it, thus showing recovery of function in the short abductor When the thumb is supported in palmar abduction, opponens can be felt rotating the thumb if put in its inner range The average time between nerve suture at the wrist and response in the short flexor in those cases where one can be sure of this sign was between 70 and 90 days For the short abductor the times were 110–140 days One-half the cases achieved grade 4 motor at 2-year follow-up, one-quarter grade 3, and a few grade 1 and grade 0

Most patients regained good function of the thumb, though only a small proportion regained completely full rotation Some patients found that they liked to wear lively splints at work many months after recovery started

Sensory recovery

Sensory recovery was almost always good and followed the same rates as those described in ulnar nerve lesions

Two-point discrimination, which is a very important function in the median nerve, takes years rather than months to return to anything like normal, and no patient was seen in the series who regained completely normal two-point discrimination after neurotmesis, though in about 25 per cent the feeling was little short of perfect

Lack of return of sensation is a very serious matter with the median nerve, but was seldom seen in this series. One-half achieved grade 4 sensory recovery at 2-year follow-up and one-third grade 3 sensory recovery.

A few regained good sensation but no motor power. In such conditions there is no question of further surgery. The patients therefore returned to work with the lively splint or had reconstructive surgery involving a flexor sublimis transplant.

On the motor side the most serious complication was lack of return of function in the short abductor. Five patients were seen in whom this muscle was the only one involved in the injury, and the muscle disability was surprisingly severe. It showed the importance of this small muscle, and that it is the main rotator of the thumb. If return of function in the short abductor does not occur within a reasonable time after the accident, then the question of a transplant should be seriously considered. The indications and technique are discussed in detail in Chapter 9. Nearly one-third of patients with median nerve lesions had only partial motor affection due either to high division, partial division or anomalous innervation.

Results in radial nerve lesions

The average time between nerve suture and the first response cannot be given as in the case of median and ulnar nerves because the conditions and levels of injury are so variable from one patient to another, but generally the rates were those expected assuming the rate of regeneration to be 1 millimetre a day.

In the stage of complete paralysis the grip is reduced to 25 per cent of that of the normal hand. When the extensor carpi radialis longus and brevis are working with power 3 (Medical Research Council scale) the grip is about 50 per cent that of normal. When the extensor carpi ulnaris and the extensor digitorum communis are recovering, the grip is between 60 and 70 per cent that of normal.

Normal grip as measured by the dynamometer does not return for many months after a good recovery is seen (grade 4 motor recovery).

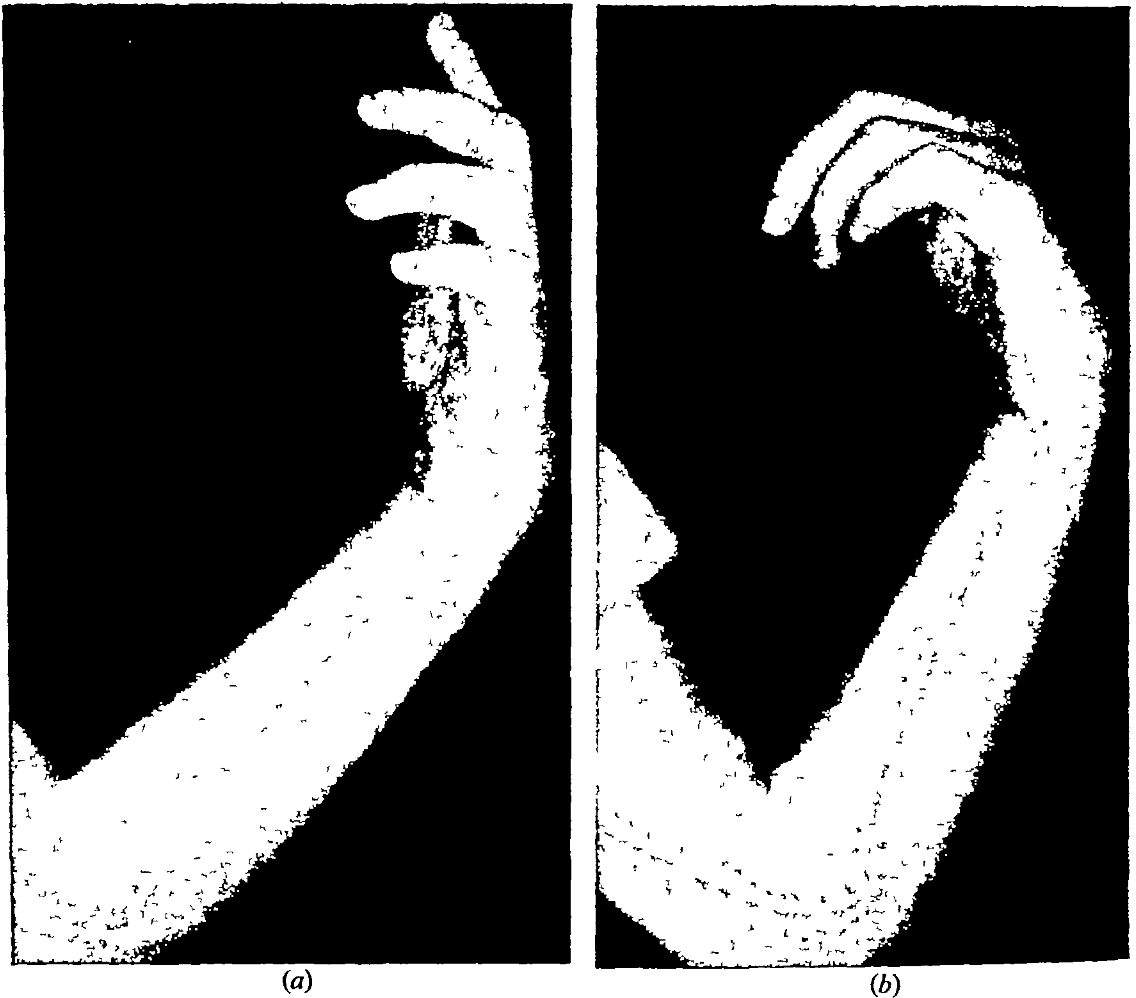
Sensation

The amount of sensory loss in radial nerve palsies varied greatly. In some there was loss over the radial part of the dorsum of the hand. In others there was sensory loss over the lower third of the forearm and fingers. There was slight diminution to pinprick over the first dorsal interosseus space in some cases, while in others the loss was only over the medial side of the dorsal surface of the limb, in some there was no loss at all. In only 1 patient in this series was there complete sensory loss in the whole area supplied by the radial nerve, and thus the sensory loss is not of importance in radial nerve palsies and careful testing is seldom necessary.

The following are some representative case histories illustrating the points discussed.

Case 1. This patient, a typical example of ulnar nerve palsy, sustained laceration of the left wrist when plunging his hand through a glass window pane. The ulnar nerve and the flexor tendons to the ring and little fingers as well as the ulnar artery were cut, 18 days after injury secondary suture of the nerve was performed 1 inch above the wrist. The flexor tendons were re-sutured and a palmaris graft was inserted into the middle finger.

The patient came to the rehabilitation centre 27 days after operation when the wrist



(*a*) (*b*)

FIG 32 —*Patient (Case 1, page 95) 27 days after secondary suture and anterior transposition of the ulnar nerve, and palmaris graft to the medialis at the wrist* (a) *Maximum extension possible* (b) *Maximum flexion possible*

was held in 50 degrees palmar flexion, only 10 degrees of movement being possible The scar was adherent at the wrist (Fig 32 *a* and *b*)

Serial stretch splints were started 6 weeks after nerve suture which reduced the flexion contracture of the ring and little fingers due to adherence of their tendons at the wrist

Seventy-three days after suture the contractures were sufficiently reduced for the application of the lively splint

A flicker was seen in the abductor digiti minimi 91 days after suture

The pin was felt 2 inches below the wrist 128 days after suture, at 142 days cotton-wool was felt 1 inch below the wrist At 262 days sensation to pinprick was present over both proximal phalanges, the lumbricals were acting and the abductor digiti minimi was graded power 3-plus There was still a slight clawing deformity of the ring and little fingers due to tendon adherence The patient returned to work 5 months after suture

About 12 months after injury the patient was readmitted to the rehabilitation centre for a short course of re-education as he was finding some difficulty in his job as an engine mechanic He was seen at this stage having been back at work for 6 months Flexion deformity at the proximal interphalangeal joint of the ring finger was 30 degrees, and at the proximal interphalangeal joint of the little finger 35 degrees Interosseus

action was just beginning A period of 3 weeks' intensive re-education resulted in good function, and the patient was discharged back to work being able to cope with all aspects of his job Even though function was so good, the grip measured only 4 lb as compared with 13 lb on the normal side Sensation to touch and two-point discrimination was normal for 6 inches below the site of suture, and so it had taken 14 months for normal sensation to return to this area of skin

The main points in this patient's case were the importance of full-time treatment in view of the severe flexion contracture, the fact that he had a tendon graft, and the skilled nature of his job The flexor tendon graft made excellent progress

Case 2 This patient severed the median nerve on a glass window pane Primary suture of the median nerve, flexor carpi radialis and flexor digitorum sublimis was performed The patient was transferred to the rehabilitation centre 2 weeks after suture where it was found that opposition was good as the thenar muscles were supplied by the ulnar nerve The patient was discharged to duty after 6 weeks' intensive treatment, having obtained full function He appeared to have fully compensated for the paralysis of the median 2 lumbricals and sensory loss did not inconvenience him in his clerical work

Case 3 In this case the patient fell on a bottle, cutting the wrist and severing the median nerve, the flexor tendons to the index and little fingers, the palmaris longus and the flexor carpi radialis Seven weeks after injury, secondary suture was performed both to the tendons and to the nerve He was transferred to the rehabilitation centre 3 weeks later when the wrist was in 30 degrees flexion with no movement and with a thick adherent scar across the front of the wrist (Fig 33 *a*)

Serial stretch splints were started 53 days after suture and were continued for nearly 3 months before the flexion contracture of the index and middle fingers was overcome

A flicker was seen in the abductor pollicis brevis 144 days after suture, and a month later there was good function in all the thenar muscles

The patient was discharged to work 6 months after the suture On review 2 years later motor function was normal in all the median supply muscles, a normal grip, sensation without overaction throughout the whole of the hand, and two-point discrimination was about 50 per cent that of the normal side (Fig 33 *b*)

This case was an example of how important it is to treat the flexion contractures intensively in the early stages Cases with a similar degree of contracture who come to the centre at a later stage require a much longer period of treatment and do not regain nearly as good function

Case 4 As the result of a motor-cycle accident this patient sustained a comminuted fracture of the left humerus at the junction of the middle and lower thirds, and developed a radial palsy at the same time He was admitted to the rehabilitation centre 2 months after injury Radiographs at this stage showed considerable callus formation which it seemed might well be interfering with the nerve Four months after the accident the nerve was explored and found to be fairly adherent to callus over a length of about 1 inch It was freed and found to be thickened

A flicker was observed in the extensor carpi radialis longus 166 days after the original injury, followed 21 days later by a flicker in the extensor digitorum communis One month later the patient stated that he was sure the arm was increasing in bulk and that the muscles felt as if they were working properly After a further 4 months there was full power in all the muscles except the extensor pollicis longus, which was still rather weak

Case 5 Severance of all the structures in front of the wrist joint was the result of this patient putting his hand through a glass window pane when sleep-walking Eight days after injury all the structures were sutured (all the flexor tendons of the wrist and fingers and both nerves)

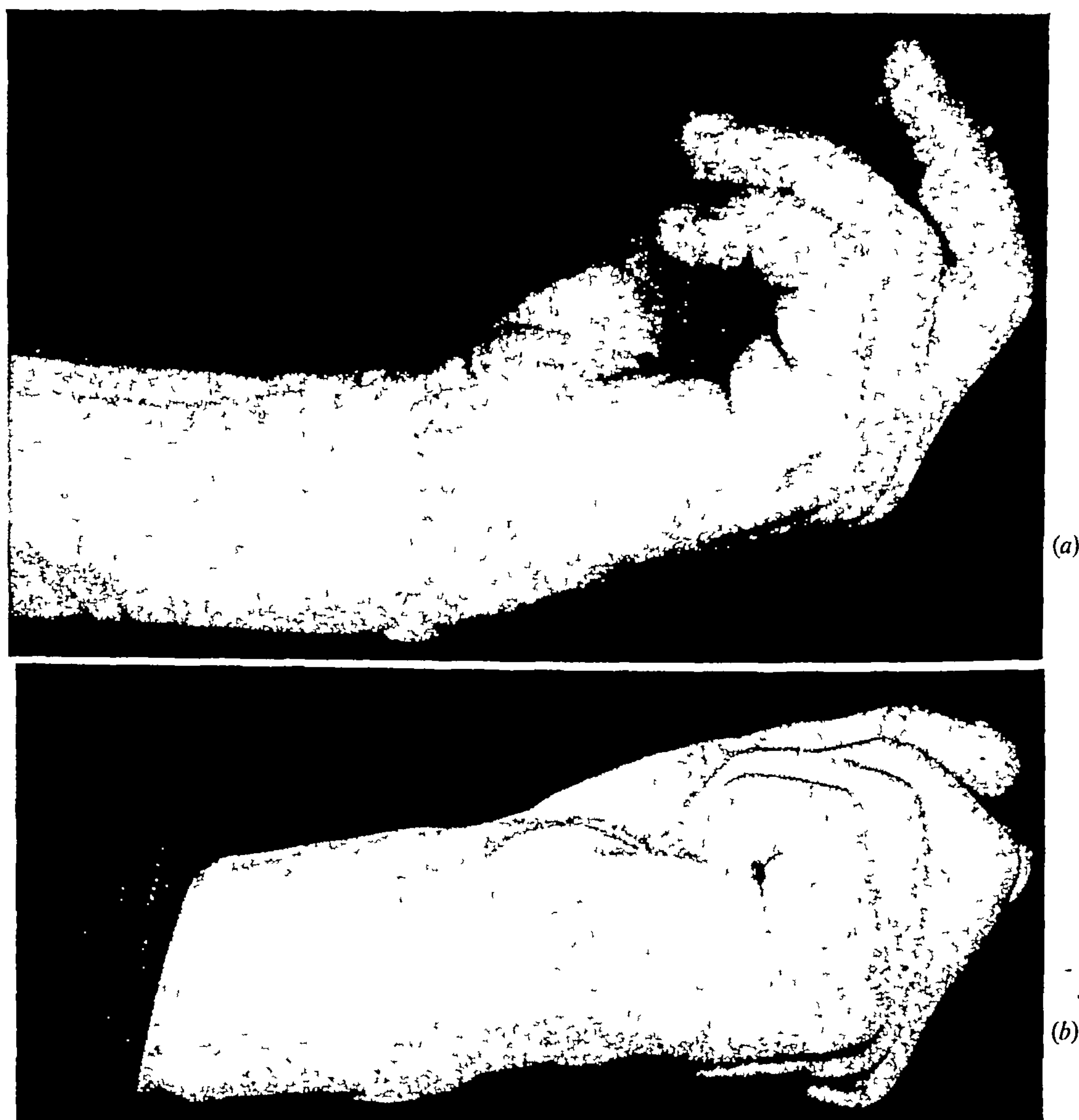


FIG 33 —*Patient (Case 3, page 97) with median nerve lesion and suture of flexor tendons* (a) *Maximum flexion* 3 *weeks after suture* (b) *Flexion* 6 *months after suture*

He was admitted to the rehabilitation centre 1 month after operation when it was found that all the tendons were just working There was an open wound across the wrist 1½ inches in length and the wrist joint was held at 30 degrees flexion, there being no movement in it The hand was very oedematous, so much so that the patient was instructed to wear a sling when not having treatment

Two months after suture, stretch splinting was started to overcome both the gross scarring and contracture at the wrist joint and the severe degree of flexor tendon adherence at the wrist, which was now becoming obvious Even 3 months after suture there was a 70 degrees flexion deformity at the interphalangeal joints with the metacarpo-phalangeal joints extended, but with the metacarpo-phalangeal joints flexed, the interphalangeal joints could be fully straightened New stretch splints were made twice a day in the first month, daily in the second month, and later twice a week The splints were worn at all times when not having treatment, also at night Stretch splinting continued for 6 months in all

A flicker was seen in the abductor pollicis brevis 151 days after suture and in the abductor digiti minimi 100 days after suture.

When discharged 10 months after suture, examination showed a grip of 10½ lb as compared with 13 lb on the normal side All the thenar muscles were working well The thumb could be opposed to within 2 inches of the tip of the little finger All the lumbricals were working, power 3-plus Independent action of the interossei had not been recovered Touch sensation had returned throughout the hand except for the tips of the ring and little fingers Pinprick was felt normally throughout the hand, there was no over-action, and general function was extremely good

At follow-up as an out-patient 24 months after suture, there was no hyperaesthesia, and two-point discrimination was the same as in the normal hand The grip was only 1 lb less than normal, all the muscles worked well The general function was assessed as grade 4 sensory and grade 4 motor, the interossei worked well He was carrying out his duties as a motor fitter with no difficulty, and had just passed top of a fitters' course when last seen He managed all heavy work and most fine work, such as handling split pins and screws, and does not need to use his sight to carry out fine work

This case illustrates that despite a very severe injury with the complications of gross flexion contracture due to tendon adherence at the wrist, an excellent result can be obtained. Full-time intensive treatment is essential in a case of this sort

Being employed as a motor fitter this patient required really good function of the hands, careful re-education was, therefore, essential Secondly, the gross tendon adherence cannot be overcome without daily stretch splints, as described in Chapter 2 Unless this is overcome motor return will, of course, be hampered seriously by the deformity Such a result can only be expected if the problem is accepted as being one that demands expert care, full-time if necessary, over a period of many months Apart from stretch splinting, oil massage to reduce the scarring on the wrist is required several times a day, electrical stimulation to all paralysed muscles twice daily during the stage of paralysis, and re-education of function when the muscles begin to recover All this takes time and cannot be satisfactorily done unless the patient is prepared to attend for treatment for the full day.

Figs 34 *a* and *b* to 41 illustrate the progress of this patient from the early stages to the final recovery.

The severance of all structures in front of the wrist is a very severe injury. Seventeen patients have been seen with such a disability and all of them required the most detailed and lengthy treatment Attention to detail meant everything in recovery of function

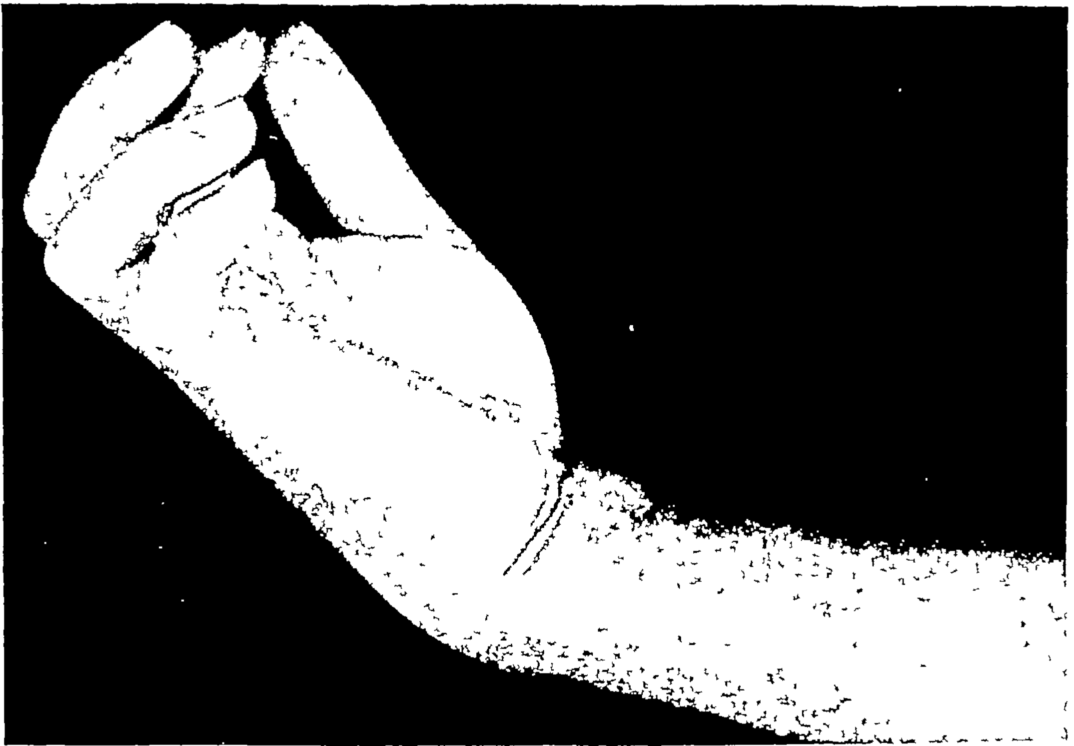
Of these, 7 achieved grade 4 sensory, 7 achieved grade 3 sensory and the rest (3 patients) grade 2 sensory, 8 achieved grade 4 motor, 8 grade 3 motor, and the other grade 2 motor Tendon function was excellent in all

It has been stressed throughout this chapter how important is regular intensive daily treatment in severe peripheral nerve lesions affecting the hand

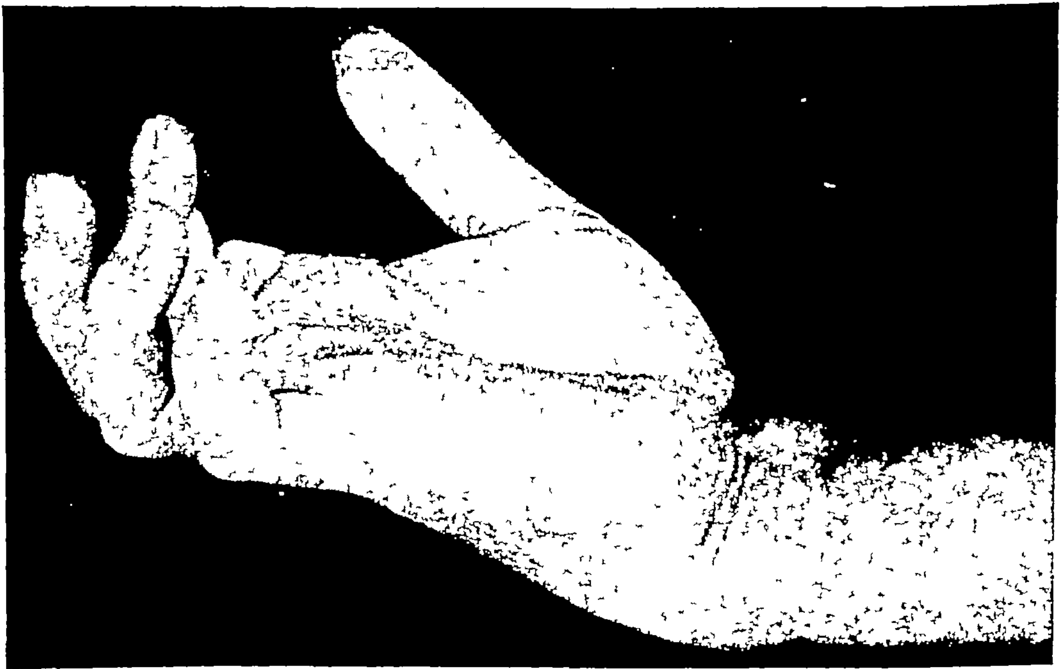
It is appreciated that this is a counsel of perfection, but in view of the importance of the hand, the aim must, wherever possible, be perfection

When patients cannot attend regularly the best must be made of what time they can spare A patient can be taught to carry out passive movements and be encouraged to use his hand at work and in hobbies as much as possible Hence, the fitting of lively splints is of paramount importance

When there is any degree of tendon adherence, the patient must be urged in the strongest possible terms to attend for regular stretches



(*a*)



(*b*)

FIG 34 —*Lesion of the median and ulnar nerves and all tendons in the right wrist Gross adherence of tendons 4 weeks after secondary suture of all structures, and at commencement of rehabilitation* (a) *Maximum flexion and* (b) *maximum extension possible at the wrist and fingers* (*This and the remaining illustrations in this chapter refer to the patient described in Case 5 on page 97*)

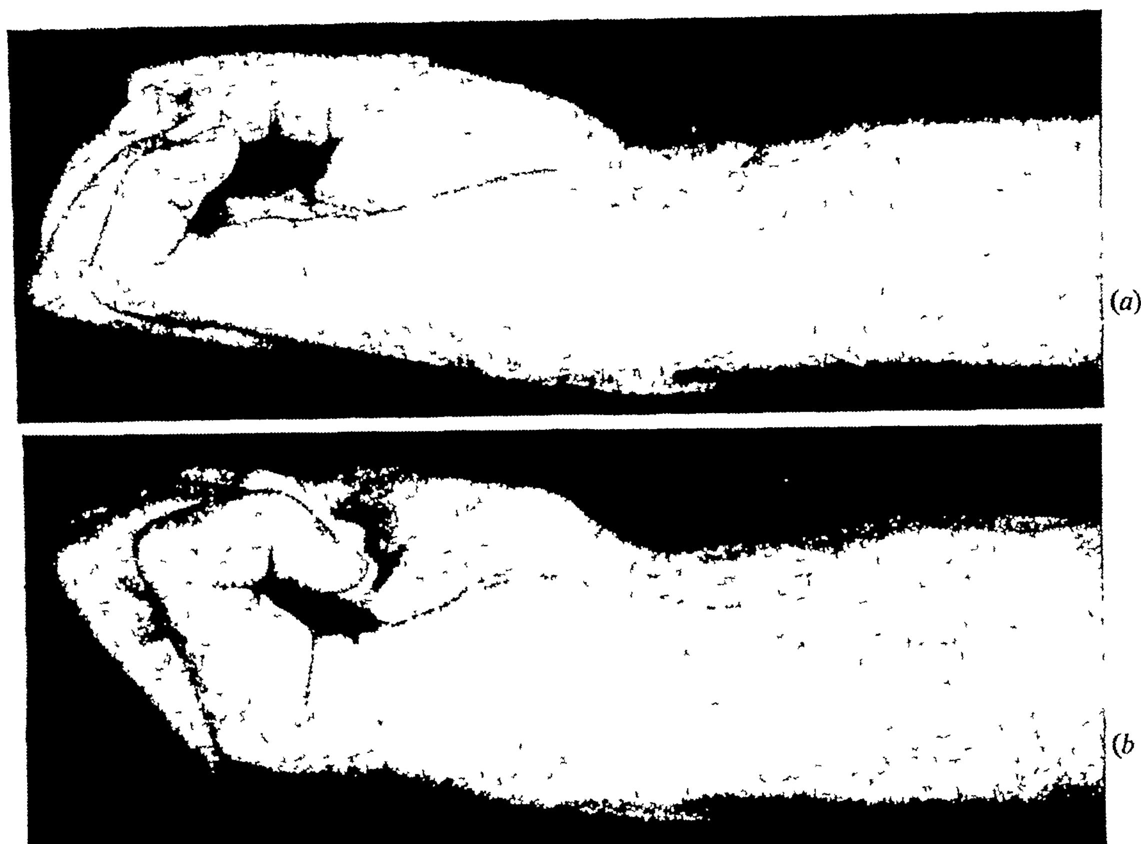


FIG 35—*Maximum flexion of fingers possible* (a) *at* 2 *months and* (b) *at* 4 *months after commencement of rehabilitation*

PRINCIPLES AND METHOD OF CONSTRUCTION OF LIVELY SPLINTS

Median nerve splint

The principles to be observed will be discussed, and one splint for each type of lesion will be described in detail

Indications

The median nerve splint is employed in weakness of the thenar muscles as occurs in median nerve lesions and poliomyelitis (Fig 21)

Principles

(*a*) The splint should place the thumb in palmar abduction (up to the short abductor lift)

(*b*) It should rotate the metacarpal and allow some opposition Rotation of the metacarpal in abduction is important Most of the abduction splints merely bring the thumb into abduction by pressure on the first phalanx, levering the joint into lateral angulation It must be remembered that the short abductor rotates the proximal phalanx at the metacarpo-phalangeal joint and opposes as far as the middle finger, and that lateral angulation is a forced movement not normally seen

(*c*) It is not necessary to abduct the thumb beyond that performed by the short abductor and opponens, once rotated and in the functional position the extensors can give radial abduction

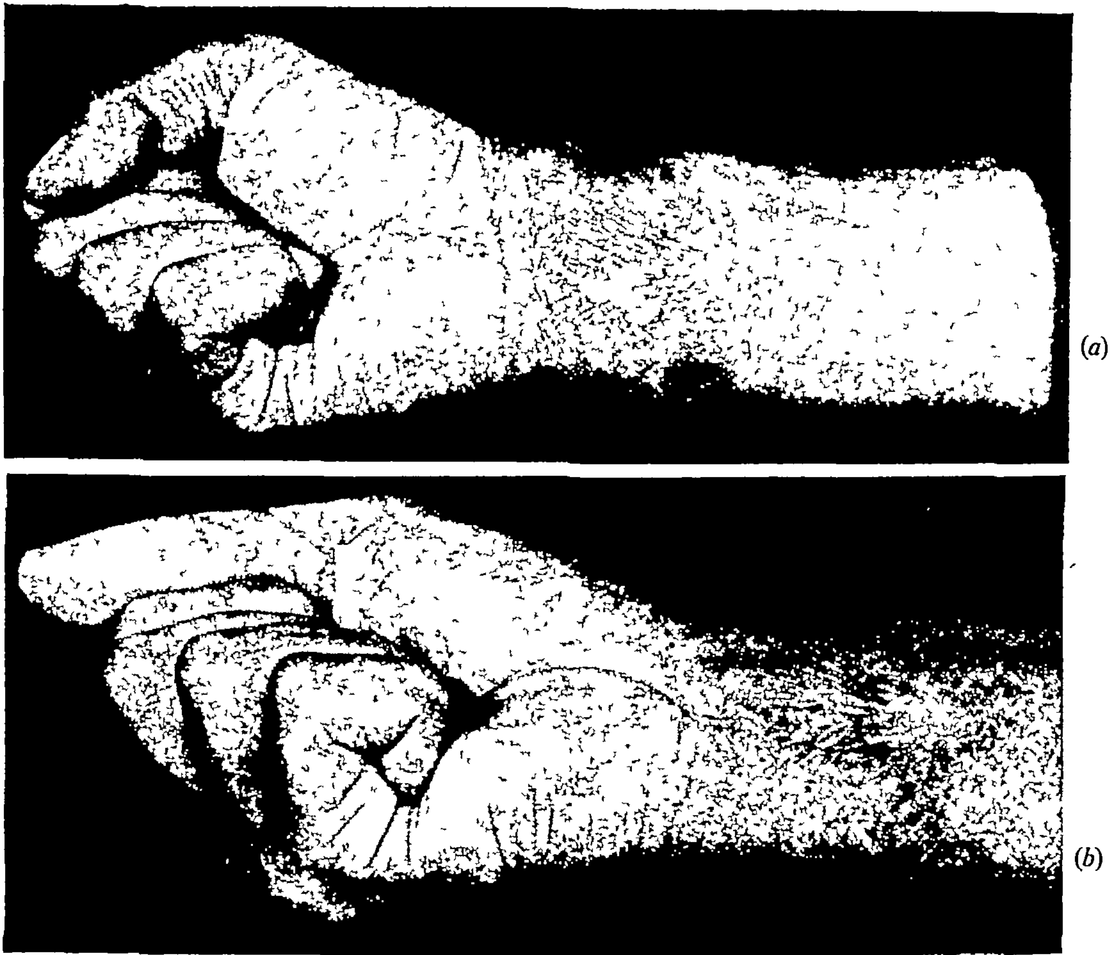


FIG 36 —*Maximum flexion of fingers possible* (a) 14 *weeks after that shown in Fig* 35*b and* (b) 1 *year after suture*

(*d*) The splint should allow full radial abduction and extension returning the thumb to the normal resting position

Method of construction

Materials required—These include calf hide, sorbo rubber sheeting ⅛ inch in thickness, 2 press studs, Vitrefoam for wrist lining, and linen thread Measurement will, of course, vary according to whether the patient is a child or an adult, and the following sizes are given only as a guide for practice and will fit the average male hand

Cut a strip of rubber approximately 1¼ inches wide by 8 inches in length Mark one end A and the other end B, 3 inches from A draw a line across the rubber

Fitting

With the patient holding the thumb in slight abduction place the marked line over the web of the thumb with A over the palm and B at the dorsal surface Draw the rubber round the metacarpo-phalangeal joint in a downward direction, folding B end round and over A towards the palm in a moulding movement Put a mark on the side B at the point of the V and a line following its edge on side A, this is to allow it to be returned to the exact positioning for stitching For stitching,



FIG 37 —*Maximum extension* 1 *year after suture*

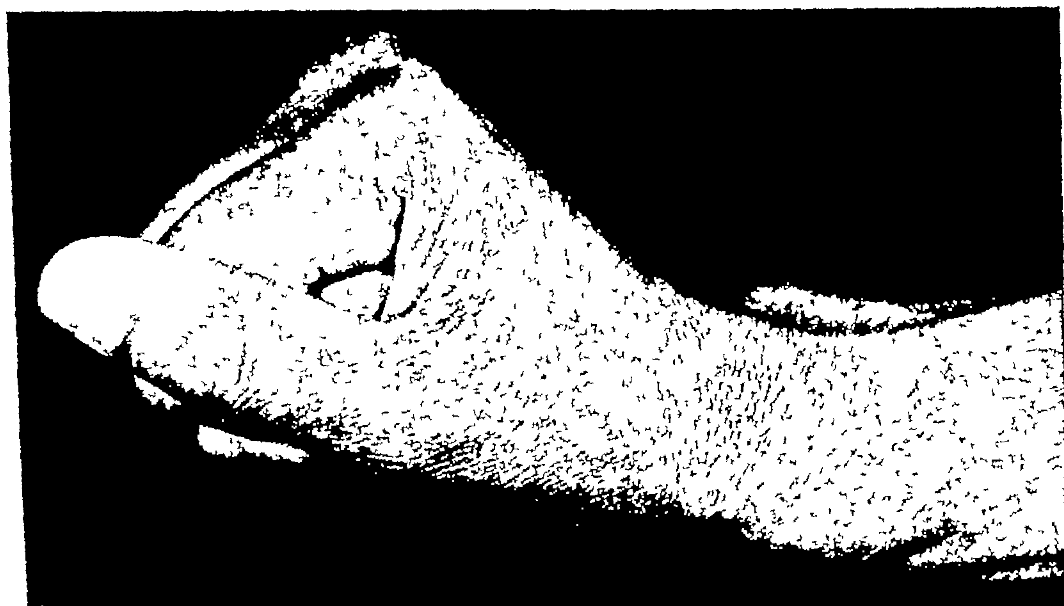


FIG 38 —*Full fist* 1 *year after suture*

the knot is placed between the pieces to avoid skin friction and 3–4 large saddle stitches are made to secure the shape (small stitches are avoided because they cut into the rubber)

Care should be taken to see that the fit is firm but not tight enough to restrict circulation When re-fitting the patient should be asked to flex the thumb, when a small lip may have to be cut away to allow the thumb full flexion

Wrist band —The correct pull of the splint depends on this band, therefore it must fit well and be lined with a non-slip material

FIG 39 —*Abduction of fingers 1 year after suture*

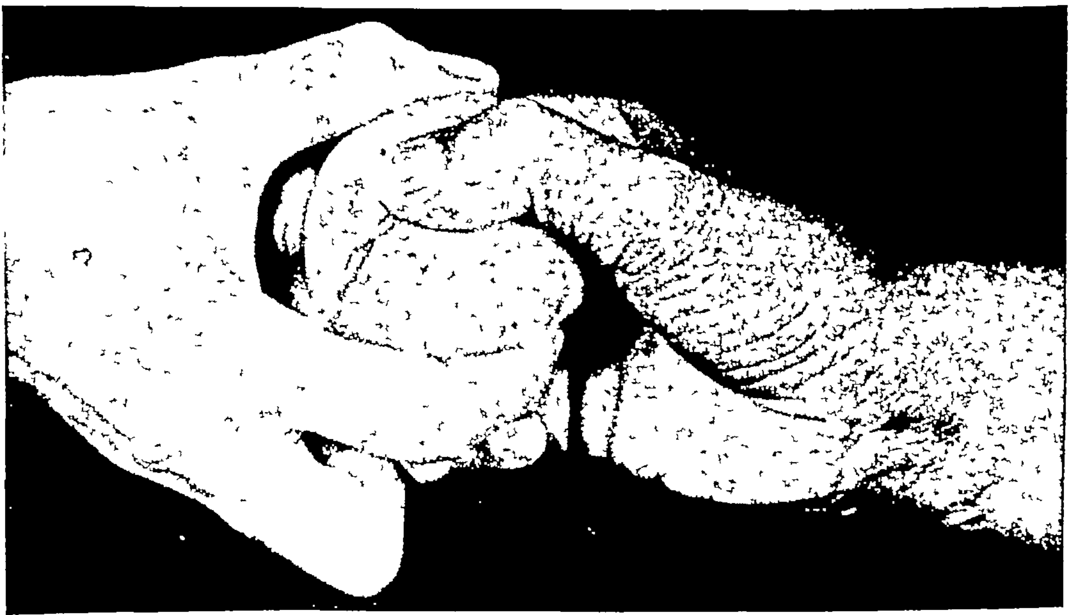


FIG 40 —*Small thenar muscle activity 1 year after suture*

A piece of calf hide is cut to the size of the patient's wrist, allowing lap over for the press studs and lining It is completed except for sticking down the lining The band is then put on the patient, with the studs on the dorsum of the wrist,

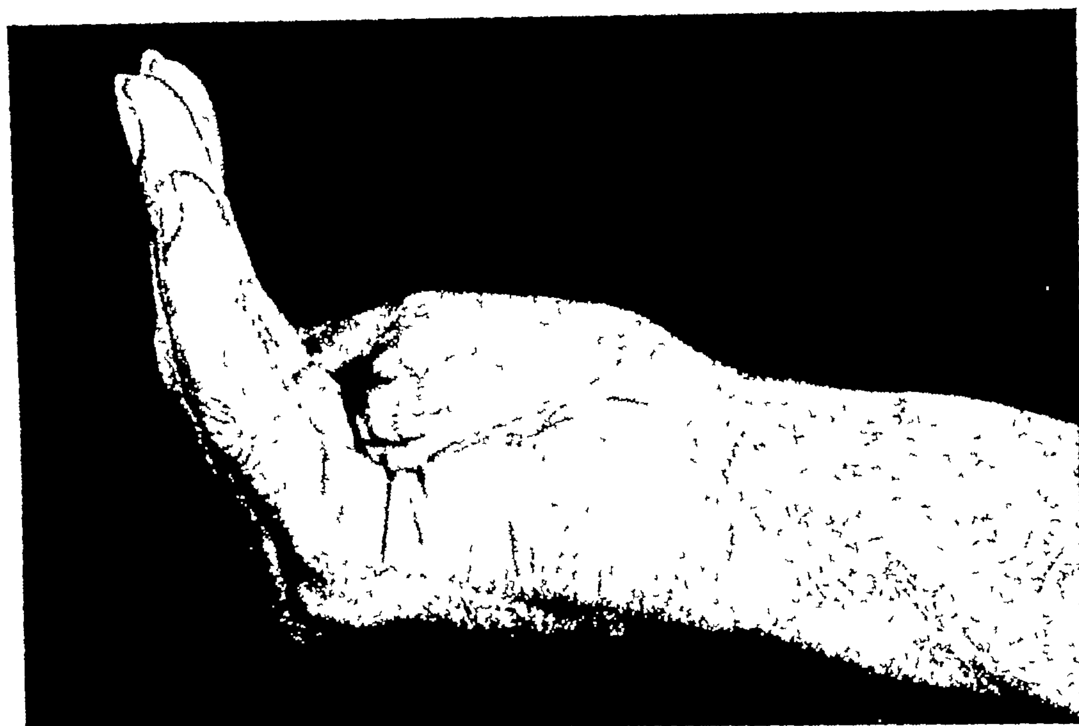


FIG 41 —*Lumbrical action 1 year after suture*

and the rubber is placed over the thumb in the correct position for the marking of its position on the wrist band

Marking onto wrist band—This is one of the most important parts of the fitting as it controls the position of the thumb but must not restrict the wrist extension

As the patient himself will be putting on the splint, there must be two points from which he can be sure of getting it into the correct position, and these are the nail of the thumb and the lateral aspect of the little finger As this is relevant to the next fitting, for purposes of explanation the long edges of the rubber will be named the palmar border and wrist border

With the thumb piece fitting well down over the metacarpo-phalangeal joint and beyond to the metacarpal, mould the wrist border round the front of the hand, at the same time lifting and rotating the metacarpal and keeping the wrist in the normal resting position until the palmar edge of the rubber arrives at the minimus border Mark the angle made on the rubber along the edge of the leather, and mark on the leather the two ends of the angle line The two pieces are then removed and the rubber stitched in saddle stitch onto the leather, the surplus piece cut off and the lining stuck in

Care must be taken to see that the patient knows exactly how to apply the splint, namely, the V of the rubber under the thumb-nail and the end of the palmar border to the lateral aspect of minimus, also, the splint should be reviewed as the calf hide is liable to stretch after being worn for a few days

If there is any tendency to pull the wrist into flexion, then the splint has not been correctly made

Ulnar nerve splint

Indications

This splint is used in any weakness or paralysis of the ulnar-supplied muscles in the hand, such as neurotmesis or axonotmesis of the ulnar nerve, in combined ulnar and median nerve lesions, in poliomyelitis affecting the intrinsic muscles, and leprosy (Fig 22)

Principles

(*a*) When in position the splint should correct the hyperextension of the metacarpo-phalangeal joints when the patient attempts to extend the fingers, returning them to slight flexion

(*b*) The splint gives support to the proximal phalanges, thus allowing extension of the interphalangeal joints with the metacarpo-phalangeal joints flexed, using the action of the long extensors

(*c*) It should allow full extension of the metacarpo-phalangeal joints

(*d*) It should correct the flattened position of the metacarpals, lifting the little and ring fingers forward at the appropriate angle in front of the middle finger, and in the combined median and ulnar lesion lift the index finger a few degrees, maintaining the concavity of the hand

(*e*) It is essential that time should be given to explaining to the patient the function of the splint and the deformity which can result if it is not worn, especially when it is not possible for the patient to have daily physiotherapy Practice with the therapist in using the long extensors in place of the intrinsics is necessary

Method of construction

Materials required—In choosing the material to use, the following factors have to be taken into consideration It must be stable, malleable and light Both the polythene group and light alloy have been used, but though they are not entirely unsuitable, we have returned always to Perspex as this seems to fulfil most nearly the functions required It is stable, but has a slight springiness, it is light and, providing there is a lamp or oven available, it is easily moulded to the required shape of the hand The following sizes are required ⅛ inch Perspex, ⅛ inch chiropody felt, a No 8 knitting needle, ¼ inch rubber bands

Two pieces of Perspex are prepared, one measuring twice the width across the metacarpal heads and the second piece the width across the phalanges in full flexion, plus 1¼ inches The long piece should be 1 inch wide and the short piece ¾ inch wide Two pieces of chiropody felt are cut the same length but ½ inch wider. This additional width is necessary to protect the skin of the patient while moulding the hot Perspex

The Perspex is placed under the lamp on a surface such as metal, which acts as a quick conductor of heat, and left for about 15 minutes When it is ready the Perspex is placed on the adhesive side of the felt and left under the lamp for a further minute to make up for heat loss The ends are then picked up with the aid of tufts of cotton-wool and, felt side to the skin, the long piece is placed over the dorsum of the patient's hand and moulded round, taking care to bring the metacarpals into their concavity The pieces on either side of the hand are brought down at almost a right angle, but the wrist edge must be twisted downwards and forwards in order to follow the decreasing width of the metacarpals from their heads to the wrist Very great care should be taken to avoid burning the patient.

The shorter piece is then shaped over the patient's proximal phalanges in a slight curve This is best done by asking the patient to flex the fingers and assisting the little and ring fingers forward in front of the middle finger

Assembling the splint

The large piece of Perspex is placed on the hand and a point is marked on each short angled piece in line with the palmar surface of the hand, and ⅛-inch holes are drilled to take the bar across the palm The knitting needle is then inserted through these holes It will be found that owing to the twist of the angle pieces the holes are not in line and one tip must be softened at a flame and the pin slipped through while it is still soft If there is surplus Perspex below the hole, this must be cut away and the whole filed to a curve, especially the area near the thumb web, to avoid any friction

One rubber band is joined to another by means of a hitch knot and each end is slipped through the two holes which will have been drilled at either end of the strip across the phalanges

The knitting needle is withdrawn from one hole and the two loops of the elastic are threaded over it when it is returned through the hole When the right tension of bands has been ascertained, the rest of the knitting needle is cut off to length and secured by tipping with sealing wax, the bar is padded with felt

Pitfalls

The bar across the hand should lie on the surface of the palm, it will press too close if the holes are sited too high up the angle piece The whole splint will slip forward if the angles do not narrow in line with the length of the metacarpals

The first attempt to make this splint should not be on an anaesthetic hand, as it does need some practice and there is a risk of burning the patient if the therapist is unfamiliar with the technique

Radial nerve extension splint

Indications

The use of the radial nerve extension splint is indicated in any condition where radial-supplied muscles are weak or paralysed, such as axonotmesis, neurotmesis of the radial nerve, poliomyelitis involving extensors of the wrist, mild hemiplegia where the patient can control flexion, and brachial plexus lesions (Fig 23)

Principles

(*a*) The splint should bring the wrist into functional extension so that the hand can be used normally and fully

(*b*) It should allow the active muscles of the wrist to assist in the prevention of oedema, maintaining all muscles at their proper lengths, and preventing capsular contractures

(*c*) It should allow full movements of the wrist, the joints of the fingers and thumb

(*d*) It is considered unwise to hold the thumb in extension for the following reasons the thumb lies in what is its normal resting position anyway, mobility of the terminal joint can be maintained by use of the short abductor (*see* page 9) except when held in extension, when held in extension the thenar muscles are under constant stretch, which is contra-indicated, and there is a tendency for the short abductor and capsular ligaments on the posterior aspect of the carpo-metacarpal

joint to shorten In no case has recovery of the thumb extensors been impaired by not splinting the thumb

Method of construction

Materials required—Materials necessary for construction of this splint are firm tanned hide for the gauntlet, a wrist type hinge, 3 two-bar roller buckles size ⅝ inch, rivets, press studs, twine, chiropody felt, 3 leather straps ½ × 15 inches

Measurements—These should be noted round the wrist and the upper forearm, to which is added 1¼ inches on each measurement to allow for lining The length from the biceps insertion to the second wrist crease is also noted

Draw a line the length of the circumference of the upper forearm, find the centre and drop a line at right angles measuring the length of the gauntlet Half the wrist measurement is drawn on either side of this perpendicular line and the sides joined up The pattern is then cut out and placed on the leather which is marked out for cutting At the same time a piece of chiropody felt is cut out, the same shape but smaller, to fit the gauntlet when it is curved round the arm

Prepare 3 leather straps as follows at one end punch a hole large enough to receive the prong of the buckle, turn the end under the buckle, and punch a hole through the 2 pieces of strap close up to the buckle to prevent it slipping about when riveted One rivet fixes the buckle and the strap to the gauntlet

Attaching the straps—The 3 straps are fixed to the gauntlet to the following measurements one is fixed 1 inch away from the wrist edge, the second one is centred and the third is placed 1¼ inches from the elbow edge

The roller of the buckles should lie to the edge of the gauntlet without overlapping and should be on the dorsal aspect The insertion ends of the straps are riveted 1¼ inches from the edge

Fitting and marking the gauntlet—The gauntlet is fitted on the patient complete with the loose lining The opening should be in line with the lateral aspect of the index finger The hand is then put into full extension in order to shape the wrist line to avoid friction and pressure, the elbow is also fully flexed and a curve cut if necessary

Marking for the spring hinge—A line is drawn just below the styloid process towards the external epicondyle, at ¾ inch below this line a piece of hide the length of the gauntlet and 2 inches in width is stitched

Fitting the hinge—The hinge of the splint should be positioned at the end of the ulnar styloid, the distal arm is cut to length, and the horizontal palmar bar fitted

Position of the horizontal palmar bar—There are two stages of positioning for this bar The first one is during the stage of paralysis and up to recovery of muscle power against gravity At this stage the bar is then lowered into the palm, and the splint worn until the wrist can be controlled when gripping

Stage 1 On the distal bar a point is marked with a scriber at the head of the metacarpal of the little finger with the wrist in full extension On this line a hole is drilled following the angle of two planes, one consisting of the direction of the palmar arch and the other the angle found by placing a ruler along the flexed metacarpo-phalangeal joints

The bar is the full width of the metacarpo-phalangeal joints, plus ½ inch The bar is then welded into the hole, drilled, and padded

Stage 2 The bar is then lowered to just below the palmar crease formed by fully flexing the metacarpo-phalangeal joints The same angles apply for the insertion of the bar, but now the bar is shortened at the point of the middle finger The bar is well padded and a leather strap is made to cover it and continue right round the hand, fastening on the dorsal aspect

Securing the splint bar to the gauntlet—The proximal bar is laid tight up to the stitching of the attached piece of leather and over the straps, the piece is moulded over the bar and secured down onto the gauntlet as firmly as possible with rivets, one rivet lying directly behind the proximal hook to prevent the bar slipping forward as the hand presses against the spring

A piece of the leather is cut out to allow the hook to be used When all construction is finished the lining is then stuck onto the gauntlet and an appropriate spring fitted

Pitfalls—If the gauntlet does not fit well the hinge piece will be forced round, this will also happen if the hide is not firm in texture Any form of sheepskin is contra-indicated A gauntlet too tight will increase oedema and defeat one of the aims of the splint

The spring should be of a tension just strong enough to return the hand to the extended position More than this will discourage the patient from using free flexion of the wrist

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CHAPTER 4

ELECTRODIAGNOSIS

DURING recent years electrical methods for the investigation of lower motor neurone disorders have received increasing recognition There has been considerable progress in the last 10 years in the accuracy of apparatus for recording the electrical responses of muscle and for measuring their reaction to stimuli

Electrical methods have now won a place in the routine investigation of peripheral nerve disorders as well as in the differential diagnosis of muscle wasting

There are three main problems in lower motor neurone lesions (1) Is there denervation? (2) If so, how much, and is it progressive? (3) Where exactly in the motor neurone is the lesion located?

There are certain well-known pitfalls in the clinical assessment of peripheral nerve injuries—trick movements can be very confusing, the extent of the lesion may not be obvious, and there may be anomalies of innervation

BASIC PHYSIOLOGY OF NERVE AND MUSCLE

Nerve and muscle are both excitable tissues, they both have a membrane which in the resting state is polarized in such a manner that the outside of the membrane is positively charged and the inside negatively charged

When a nerve is excited either naturally or by an outside stimulus, the membrane is depolarized and there is a potential change across the membrane resulting in the outside of the membrane becoming negative This depolarization is transmitted down the length of the nerve so that the nerve impulse can be looked upon as a wave of negativity travelling down the membrane On arrival at the nerve terminal, the chemical transmitter acetyl choline is released which, in turn, produces the local depolarization at the muscle end-plate This in its turn produces a depolarization of the muscle fibre membrane which is conducted from the end-plate along the whole of the muscle and the muscle fibre contracts

The earliest methods of electrodiagnosis used the response of nerve and muscle to long and short duration currents This is the basis of the faradic-galvanic test first described by Erb (1883)

Although this test has now been superseded by more accurate methods, it is still sufficiently widely used in Great Britain to deserve a detailed description and discussion of the reasons for its inaccuracy

The conventional test is as follows

The muscle is first stimulated with the output of a galvanic battery, and the quality of contraction, whether brisk or sluggish, is noted The muscle is now tested with a faradic current from a faradic coil and the presence or absence of contraction noted A normal muscle is said to respond briskly to the galvanic current, and briskly also to the faradic current with a low output A denervated muscle, however, reacts to the galvanic current with a sluggish response, and is said not to respond to faradism During re-innervation the muscle may begin to respond to faradism with a very high output—the so-called weak faradic response

The following are a few of the serious drawbacks to the use of this test in practice

(1) A patient may show return of voluntary movements after a nerve injury before the faradic response becomes positive. In the experience of some workers this is more likely than not to happen, thus making the test quite useless as a prognostic sign

(2) A denervated muscle is quite capable of responding to faradism This has been reported by many workers over the last 40 years but little notice seems to have been taken of their observations Many people are under the impression that there is some magical property of the faradic current that allows it to stimulate normally innervated muscle but does not allow it to stimulate denervated muscle Provided that sufficient current is given, most denervated muscles will respond to a faradic current

In the author's series of 200 cases of peripheral nerve injuries, 76 per cent of 360 muscles known to be denervated showed a response to faradism

Ritchie (1954) pointed out the paradox that the better the physiotherapist the more likely are the results of faradic galvanic tests liable to be wrong in her hands The good physiotherapist will be able to persuade the patient to take the greatest amount of current, and she will also be able to make the most use of her apparatus. She will thus be able to obtain a higher percentage of responses of the denervated muscle to the faradic impulse than her more timid colleague, who will not press the output too far Consequently, she will report more muscles as recovering when, in fact, they are denervated It is, of course, the interpretation of the test that is at fault It will be seen later that the faradic impulse is merely one point on the strength duration curve of the muscle, and it depends on the rheobase of the muscle as to whether a response is obtained at this duration.

(3) The test is a qualitative one—the response is either present or absent, and no comparison can be made from one examination to another As a positive response depends to a large extent on the threshold of the muscle, and this threshold often rises with re-innervation, it is not surprising that the response is often not obtained when obvious voluntary movement is present Paradoxically, therefore, a positive response may become negative as the muscle becomes re-innervated

The newer methods involving the use of strength duration curves are not only more accurate and more convenient for the patient, but, in fact, take less time than the old faradic-galvanic test The use of the latter is, therefore, to be condemned and there is no longer any place for its use today.

STRENGTH DURATION CURVES

Rationale

Modern methods of electrodiagnosis involve the measurement of the excitability of nerve and muscle—the so-called strength duration curve In this method a long duration electrical impulse (100 milliseconds or longer) is passed through the muscle under test, and the amount of current measured in milliamperes or volts required to cause minimal perceptible contraction is measured Similarly, the threshold of contraction at progressively shorter durations up to 0 01 milliseconds is measured, and a curve relating strength of current to duration of impulse is drawn When the muscle is normally innervated, the current stimulates the fine

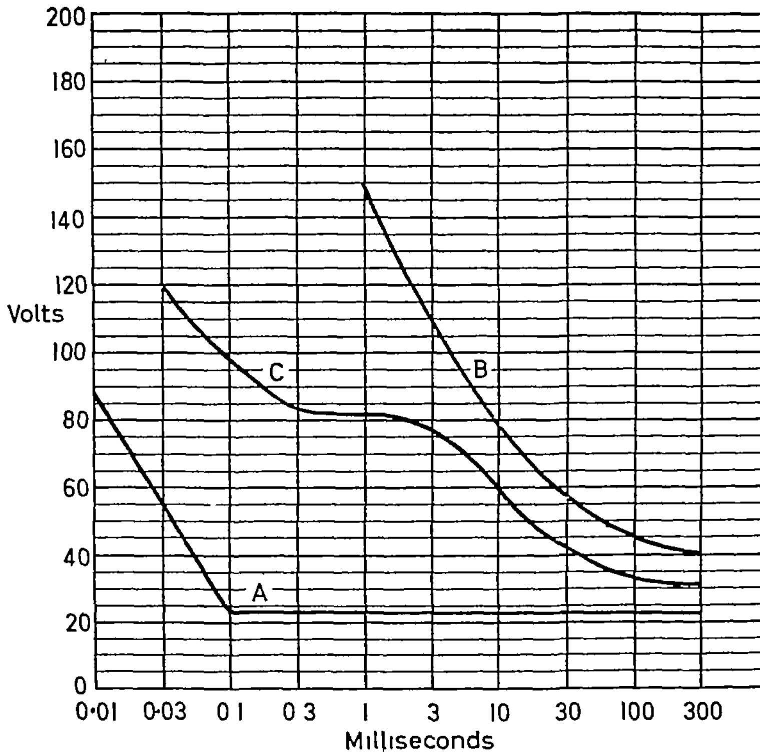


FIG 42 —*Strength duration curves on normal (A), denervated (B), and partially innervated (C) muscle The top left-hand portion of curve (C) represents the activity of re-innervated fibres (compare with (A)), the bottom right-hand portion represents the activity of still denervated fibres (compare with (B))*

intramuscular nerve fibres which are, of course, much more sensitive than the muscle fibres Thus, the typical excitability response of nerve is obtained (Fig 42A)

In a totally denervated muscle, the current stimulates the muscle fibres direct and the characteristic response of muscle is obtained (Fig 42B)

During re-innervation a kinked or broken curve is obtained (Fig 42C) which shows elements of both curves, the upper left-hand portion representing the response of re-innervated fibres, being similar to the normal nerve response, and the lower right-hand portion being that of muscle and similar to the muscle response The curve thus shows the ratio of re-innervated to denervated fibres and allows a rough quantitative expression of the degree of re-innervation

The value of current at the longest pulse duration is known as the " rheobase " This is an important measurement and is defined as the amount of current flowing for infinite duration required to cause just perceptible contraction

For practical purposes infinite duration is in the order of 100 milliseconds or longer The rheobase is thus a measure of an amount of current, and represents the basic threshold of the tissue below which it is impossible to excite it for however long the current flows Thus, in Fig 44A, if the curve of the nerve response was prolonged to the right it would still be a straight line because the response to 100 milliseconds represents the threshold of that tissue Thus, the two curves for muscle and nerve are, in fact, the same shape, the only difference being that the curve for muscle is shifted to the right, that is, muscle is less excitable than nerve

This difference in excitability between muscle and nerve is represented by a concept known as chronaxie—meaning the length of time, expressed in milliseconds, for which a current of value twice the rheobase must flow for just perceptible contraction In the curves of muscle and nerve in Fig 44, the values of chronaxie are determined by finding out where on the time scale a value of twice the rheobase cuts it so that the value for the nerve response is just greater than 0 03 milliseconds, and that for muscle is 10 milliseconds

Chronaxie values have for a long time been used in the assessment of the state of the lower motor neurone, and some workers actually used special apparatus known as chronaximeters, long values representing the presence of denervation and the short values the presence of innervation The chief drawback to the use of chronaxie is that the values are always either short or long, intermediate values not occurring Furthermore, as will be seen later, long values of chronaxie may co-exist with obvious signs of re-innervation on the strength duration curve, whilst short values may be found with obvious signs of degeneration on the strength duration curve Consequently, there is no place today for the use of chronaxie measurements in electrodiagnosis, though the concept certainly served a useful purpose for the development of the subject

Polar formula

This test has a long history, it was noted many years ago that the amount of current required to cause minimal contraction was less when the cathode was used as the stimulus than when the anode was used and for a normal muscle, cathode closing contraction was said to be greater than the anode closing contraction, or, as it was expressed, K C C > A C C Conversely, in denervation, the reverse was true, or A C C > K C C This test is even more unreliable than the faradic-galvanic test and should never be used

Technique

As good results depend so much on accuracy of technique, this will now be described in detail

Two techniques are available for placing the electrodes—either two small disc electrodes can be placed on either side of, and at equal distances from, the motor point (in denervated muscle, the point at which the best contraction is obtained) or an active electrode is used to stimulate the muscle and a large dispersive electrode is placed elsewhere on the limb, preferably opposite the active electrode and as near to it as possible

Both methods have their uses, the longitudinal method using two small electrodes limits the spread of current to neighbouring muscles, which can be most helpful when those muscles are normally innervated, for spread to those muscles may mask the slight contraction of the affected muscle On the other hand, the active electrode technique is most useful when searching for areas of denervation within a muscle, or when, of course, carrying out nerve conduction tests With either method, the pulse duration selector switch is set at the longest duration 100 or 300 milliseconds and the current gradually increased until the contraction is seen The current is then slowly decreased until the muscle is just seen to contract and lowering of the current by only a fraction causes it to disappear The point at which the just perceptible contraction is seen is by definition the rheobase, and the duration is then shortened to the next pulse duration without altering the

output and the amount of current for minimal contraction again measured Similarly, this value is measured for each value of pulse duration until no response can be detected with the maximum output available, or if there is response at each pulse duration the value is obtained for the shortest The curve relating strength of current and duration of impulse can now be drawn

There are certain points which require emphasis if consistent results are to be obtained First, the muscle must be reasonably warm and well lit—it is usual to perform these tests under radiant heat, which provides warmth to the muscle and illumination Secondly, electrodes must be well moistened in warm saline solution and should not be allowed to dry during tests, an unlikely occurrence in short tests, but if tests take an unusually long time, electrodes should be kept moistened throughout

When muscles insert by easily palpable tendons—as, for example, the anterior tibial group and the wrist extensors—the threshold is best measured by feeling for the tendon rather than by watching for muscle contraction

Choice of stimulator

The choice of stimulator requires some discussion Nowadays, with modern electronic stimulators, the plotting of the strength duration curve becomes in good hands a highly accurate physiological investigation As the results when using such a stimulator are so reliable and small changes in the curve so significant, it is important that the best stimulators available should be used They are not expensive and one need cost no more than £50 There are two main types of stimulator in use, known as the " constant current " and the " constant voltage stimulator "

Constant voltage stimulator

The constant voltage stimulator has a low output impedance (500 ohms or less), and a known voltage is produced across the output terminals The output is thus measured in volts

Constant current stimulator

The constant current stimulator has a high output impedance (100,000 ohms or more) which permits rigid stabilization of the current between the electrodes and output is thus measured as milliamperes

There has been much controversy about the merits of these two stimulators. Supporters of the constant current stimulator claim that this technique is more accurate as it is independent of changes in skin resistance, they claim further that unlike the voltage technique, no preparatory measures need be taken to reduce skin resistance The voltage technique, it is said, involves careful cleaning and warming of the skin. Supporters of the constant voltage technique point out that it is much less painful for the patient than the constant current technique

Recent work by the present author has shown that skin resistance is much less important than was once thought Provided that the skin is reasonably clean and not obviously cold, results are perfectly constant, and with the undeniable advantage of a more comfortable stimulus, particularly in children, nervous patients, and in patients who require repeated testing, the constant voltage technique has outstanding advantages. Furthermore, a comparison between strength duration curves plotted by two stimulators on a series of patients with muscles in a variety

of stages of re-innervation, showed that kinks were more obvious with the constant voltage technique

For routine use in the detection of denervation, both stimulators give equally good results providing, first, that the technique used is a careful one and the operator experienced Secondly, that a reliable stimulator is used

When using strength duration curves for assessing the progress of curves for re-innervation and denervation over a period of time, the present author feels strongly that the constant voltage technique has such definite advantages that it is preferable to the constant current technique

The accuracy of the stimulator is, of course, extremely important It must be tested regularly in the laboratory, at least once every 6 months, as slight alterations in performance may not become obvious clinically

On purchasing a stimulator one should ensure that the manufacturer has adequate testing facilities for correcting parameters such as pulse duration and amplitude

Testing of individual hand muscles

Most hand muscles are readily accessible for the plotting of strength duration curves The following techniques have been found reliable by the present author.

Abductor digiti minimi

This is the best muscle to test when the first signs of regeneration in an ulnar nerve lesion at the wrist are sought

With the elbow flexed to about 145 degrees, the hand is laid with the thumb downwards on the table and the forearm fully pronated, thus affording good access to the hypothenar eminence which is then vertically placed.

Interossei

The hand is placed palm downwards on the table and the electrodes placed in the interosseus space The longitudinal reaction is particularly useful here as it prevents spread to the long extensors which are in close proximity

Thenar muscles

The abductor pollicis brevis and flexor pollicis brevis are tested with the hand palm upwards, and the thumb should be relaxed and laid just on top of the index finger

Long extensors

With the palm downwards the long extensors are easily tested Again, the longitudinal reaction is preferable as there are so many muscles lying close together in the forearm

Sluggish response

The normally innervated muscle responds briskly to either a short or long duration stimulus, a denervated muscle, however, responds sluggishly The degree of sluggishness depends on the temperature of the muscle—the colder the muscle the more sluggish the response There is, however, no difficulty to the practised eye in distinguishing the sluggish from the brisk response, even when the muscle is very warm However, the response may well be sluggish when there are obvious signs of re-innervation, conversely, the response may well be brisk in the presence of signs of denervation When a sluggish response is obtained one can be quite

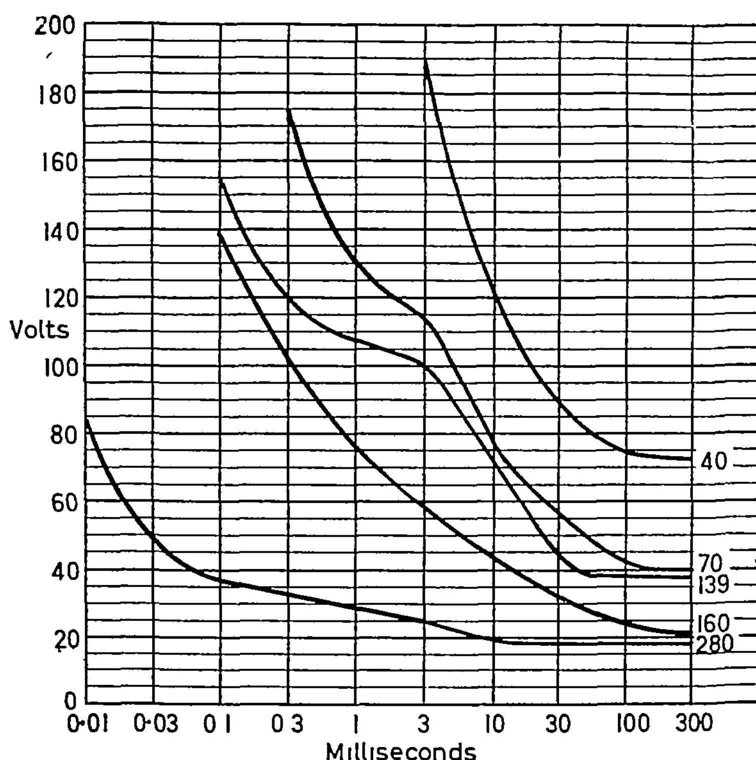


FIG 43—*Strength duration curves on the abductor digiti minimi in a recovering ulnar nerve lesion From above down the curves are 40, 70, 139, 160 and 280 days respectively after secondary nerve suture All the signs on the curve of progressive re-innervation are seen—shift to the left, lowering of slope, and development of kinks*

certain that some denervation is present, and this is a very reliable sign, thus the quality of response should always be noted when plotting strength duration curves

Changes in the strength duration curve with regeneration of nerve

The earliest signs of re-innervation on the strength duration curve is the appearance of a slight kink, this usually precedes a clinical contraction by about 6–8 weeks As re-innervation proceeds, three changes in the curve are noted (1) the kink becomes more obvious and occupies an increasingly greater part of the curve, (2) more points appear on the curve, that is to say, a response is obtained at progressively shorter pulse durations, and (3) the whole threshold of the curve drops (Fig 43) It will be seen that these three changes are indications of the transition of a denervated curve to the normally innervated curve—the curve is, in fact, moving to the left and down to the base line Recalling that the strength duration curve allows an assessment of the ratio of innervated to denervated fibres, it is seen that it will give a fairly accurate picture of the progress of re-innervation, conversely, the changes in the reverse direction indicate the progress of degeneration (as, for example, in a progressive ulnar neuritis)

Fig 43 shows the progress of the strength duration curve from total denervation to complete recovery in a patient with a sutured ulnar nerve These curves are the most helpful means of checking on re-innervation, not only do they allow detection of re-innervation much earlier than clinical signs, but they will also indicate if there is some bar to progress

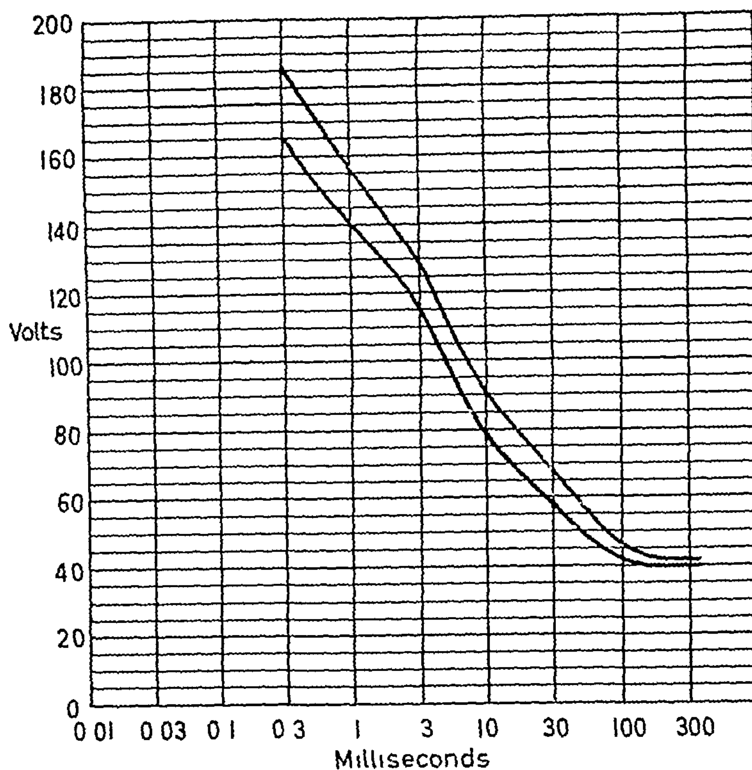


FIG 44 —*Two strength duration curves at 6-month intervals on the abductor pollicis brevis in a patient with a median nerve palsy which showed only slight recovery The curves are typical of partial denervation and indicate that there has been no change in innervation over this period*

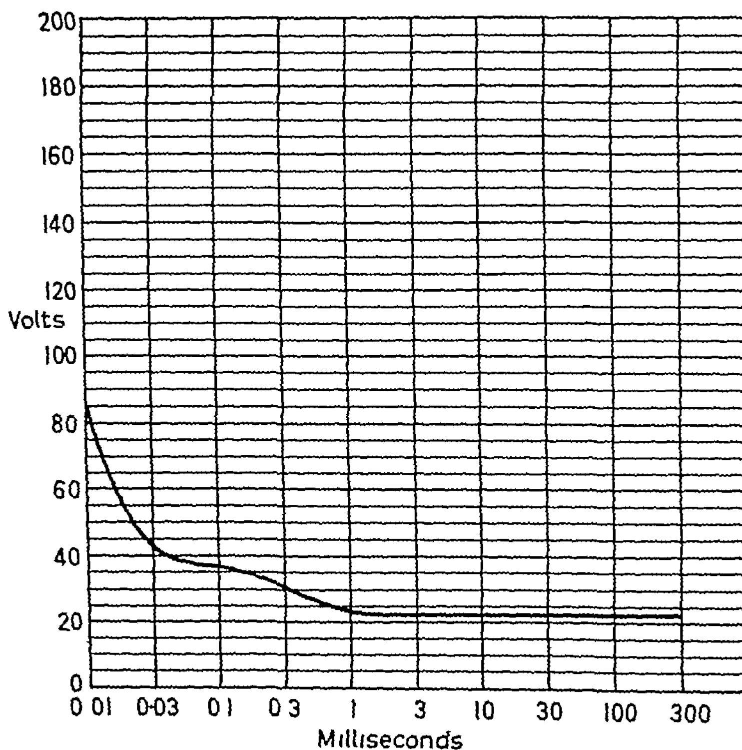


FIG 45 —*Strength duration curve in a patient with early signs of ulnar neuritis There are slight signs of denervation.*

Fig 44 shows the strength duration curves in a patient with a recovering nerve lesion in which 2 curves are seen to be identical, even though separated by a 4-week interval This suggests that further recovery had ceased (a neuroma was confirmed at operation) Similarly, a slight change in the strength duration curve from normal with a small kink definitely indicates the presence of degeneration Fig 45 shows a curve seen in a patient with the symptoms of early ulnar neuritis The detection, as early as possible, of slight signs of degeneration of the ulnar nerve is of vital importance, so that ulnar nerve transposition can be undertaken without delay

It should always be remembered when using strength duration curves that they are the most accurate means of investigating the state of the neuro-muscular system If the technique is careful and the stimulator reliable, slight changes in the curve are of significance Once the operator is practised he can trust his results and should not regard a slight kink as being probably due to one point being slightly out of line

Summary of the use of strength duration curves

(1) The strength duration curve will show whether there is any sign of denervation and if so, roughly how much

(2) Serial curves will show the progress of re-innervation or denervation

(3) The changes in the curve associated with progress of re-innervation are so reliable that failure to find them indicates a hold-up in regeneration

(4) The stimulator will only allow information on those muscle fibres that are stimulated between the electrodes In a large muscle, such as the quadriceps, the state of innervation in the deeper part of the muscle may, of course, be different from that in the superficial part

However, the findings in a strength duration curve in any of the muscles of the hand should be applicable throughout the whole muscle

(5) The stimulator used must be reliable, the operator must be experienced in obtaining the best results, and it must be appreciated that it is an accurate physiological investigation that is being undertaken

NERVE CONDUCTION

Technique

Before plotting strength duration curves, the ability of the nerves in the limb to conduct an electrical impulse should be tested

In the upper limb a dispersive electrode is placed behind the neck and an active electrode used to stimulate the branches of the brachial plexus in the neck at Erb's point By moving the active electrode around, the three trunks can be stimulated and the contraction in the appropriate muscle groups of the limb is observed The radial nerve can be stimulated in the upper arm in the spiral groove The ulnar nerve can be stimulated behind the medial epicondyle and at the wrist just lateral to the flexor carpi ulnaris The median nerve can be stimulated just medial to the bicipital aponeurosis and at the wrist just medial to the tendon of the palmaris longus The equivalent nerve should be tested on the normal side first and the threshold for conduction measured If no response is obtained with a current of at least double the normal threshold, nerve conduction can be said to be absent.

Uses of nerve conduction

The detection of anomalies of innervation

In a patient with damage to the median nerve at the wrist, for example, and in whom there is some contraction of the thenar muscles, it is important to decide whether this is a partial lesion of the median nerve or whether the ulnar nerve is supplying one or more of the thenar muscles Stimulation of the ulnar nerve will solve this problem

Distinguishing partial from complete lesions

If nerve conduction is present when there is clinical paralysis, it indicates that the lesion cannot be complete The corollary to this is not, however, true, there may well be a partial lesion and no nerve conduction obtainable It is a recognized fact that a nerve may be able to conduct impulses and thus show voluntary contraction without being able to conduct an artificial impulse Thus, in distinguishing a partial or complete lesion, the presence of conduction is significant but its absence is not sufficient to obviate further electrical investigation

Neurapraxia

When conduction in a nerve is blocked there will be clinical paralysis and in the early stages there may be no other signs, such as wasting or circulatory disturbance, to distinguish a neurapraxia from an axonotmesis The detection of nerve conduction in such a case will certainly show that the lesion is at any rate not complete

If strong contraction in all the muscles is obtained on nerve stimulation, a neurapraxia can be confidently diagnosed It is, however, advisable to plot strength duration curves on one or more of the affected muscles in order to determine if there is some element of denervation in the lesion

A pure case of neurapraxia lasting for more than a fortnight is exceptionally rare—almost inevitably one finds that there is some evidence of denervation, however slight The signs of denervation do not appear fully for some days after the lesion Nerve conduction may be present for 3–4 days after a complete severance of a nerve, though usually it will be with a much higher current than normally Similarly, the strength duration curve may show the curve typical of a partial lesion a few days after a complete nerve section and it is, therefore, of importance to see whether this is a lesion in the process of degenerating or a partial lesion which has ceased to degenerate

Absolute evidence of complete denervation cannot be expected for 14 days after a lesion, though if there is nerve conduction present and the muscles react strongly 7 days after the lesion, it is not likely that the lesion will be a severe one It is, however, wiser to postpone electrical tests in peripheral nerve lesions for 14 days after injury Nerve conduction may be absent also when there is gross oedema or ischaemia, and in these conditions a complete strength duration curve may be very difficult to obtain.

ELECTROMYOGRAPHY

In recent years electromyography has come to the forefront in electrical investigations of neuro-muscular disturbance, highly accurate and convenient apparatus is now available and the rationale and scientific background to the discipline has been adequately worked out

The main use of electromyography is in the localization of a lesion to the particular part of the lower motor neurone

The strength duration curve, as has been shown, allows the assessment of the ratio of innervated to denervated fibres, but the curve will be the same for a partial lesion of a peripheral nerve and for a partially paralysed muscle in poliomyelitis The curve gives no indication as to where the lesion is, whether in the peripheral nerve or in the anterior horn cell the electromyograph, however, does just this

Physiological background

When a muscle fibre contracts its membrane becomes depolarized, thus, the electrical charge on the outside of the fibre membrane is reversed from the resting positive to a negative charge and this returns to normal after contraction The electromyograph is a device for recording this electrical change and displaying it on a screen as well as recording the noise on a loudspeaker The contraction of a single muscle fibre is represented on the electromyograph by a single diphasic potential of amplitude 100 microvolts and duration 1 millisecond (Fig 46)



FIG 46 — *Fibrillation potential (left) Small normal motor unit action potential (right)*

The normal motor unit consists of one anterior horn cell, its peripheral axon and some 150 muscle fibres, thus the response of a motor unit consists of the algebraic summation of 150 muscle fibre action potentials There is naturally some temporal dispersion and the resulting wave-form as seen on the electromyograph is a diphasic wave of average duration—5–7 milliseconds and amplitude $\frac{1}{2}$–2 millivolts (Fig 47)

The muscle fibre potential, that is, the electrical activity associated with the contraction of a single muscle fibre, is known as a fibrillation potential The response of a motor unit is known as a motor unit action potential.

Basically the electromyograph consists of a fine concentric needle electrode which records the electrical activity of the muscle and relays it through various stages of amplification to the cathode ray oscilloscope and through a loudspeaker With the needle inserted into the muscle under examination, any activity at rest is looked for In the normal muscle there is no spontaneous activity at all When the muscle contracts, the first sign on the screen is the appearance of one or two



FIG 47 —*Normal motor unit action potentials*

low amplitude motor unit action potentials The appearance on the screen is known as discrete activity

With further effort and increasing contraction both the number of motor units and the frequency of their discharge increases This produces on the screen a picture as illustrated in Fig 48 and is known as a partial interference pattern

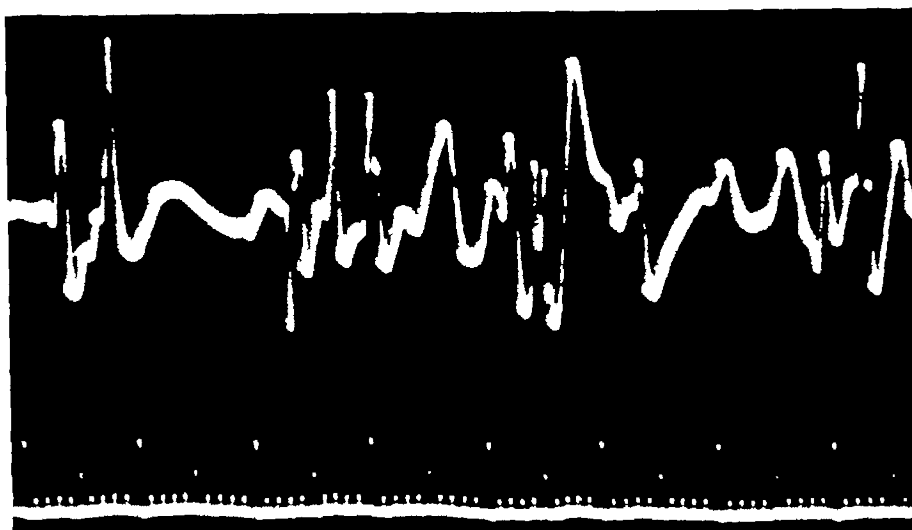


FIG 48 —*Partial interference pattern of motor unit activity Time scale 10 milliseconds between large spikes*

It is so named because in some parts of the trace discrete action potentials can be seen, in others the trace has been obliterated by intense motor unit action potential activity The picture, known as a complete interference pattern, is associated with maximal contraction (Fig 49) At this final stage of contraction large action potentials of 10 or more milliseconds duration and 2 millivolts and upwards appear The small action potentials which initiate voluntary contraction are produced by the small anterior horn cells in the spinal cord The large action potentials are similarly produced by the large anterior horn cells

Electromyographic signs of denervation

When a muscle is totally denervated, some 18 days after denervation the muscle fibres start spontaneous contraction at a rate varying between 2 and 10 a second It seems that the absence of their controlling nerve cuts them off from some trophic influence, and after a time they revert to their old embryonic behaviour

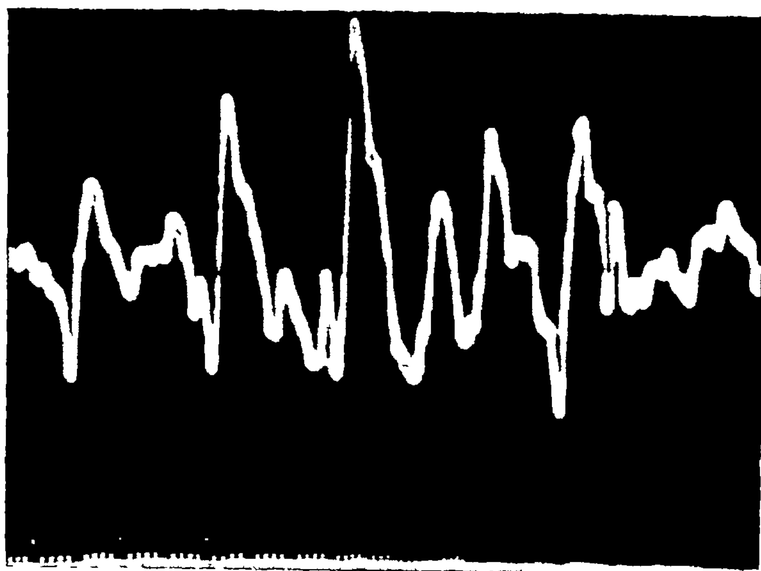


FIG 49—*Complete interference pattern of normal motor unit activity*

of contraction In the embryo the muscle fibres are in constant rhythmic spontaneous contraction before innervation This represents their inherent property of contracting The electromyograph can detect this activity and on the screen will be seen a number of spontaneously occurring fibrillation potentials They have a highly characteristic high-pitched clicking noise and they occur spontaneously and with a regular rhythm They persist throughout denervation provided that the muscle is still viable, and only disappear when the muscle becomes fibrosed or re-innervated The degree of muscle activity depends on how the muscle is being treated A muscle having good physiotherapy and regular electrical stimulation fibrillates freely The detection of fibrillation potentials indicates for certain that denervation is present A muscle may, however, be denervated and yet not show any fibrillation potentials In fact, in some 20 per cent of denervated muscles fibrillation may be very difficult to find If the muscle is well warmed before investigation, the fibrillation potentials are easier to detect It is said that the amount of fibrillation activity falls off sharply just before re-innervation, but this has not been confirmed by the author in a series of 250 nerve injury studies Fibrillation will only fall off as the muscle being examined becomes re-innervated

Electromyographic signs of re-innervation

Signs of re-innervation on the electromyograph are the appearances of so-called complex or polyphasic action potentials These represent activity of the newly-formed motor units In the very early stages of re-innervation, there will be only 1 or 2 fibres in the unit, and thus very small potentials are seen These are of the order of 2 milliseconds duration and 150–500 microvolts amplitude They are polyphasic, that is, complex in shape (Fig 50)

As re-innervation proceeds and more muscle fibres make up the motor unit, so does the duration and amplitude of the action potential increase At an advanced stage of re-innervation, these potentials can be many times the duration of normal, and they have been seen up to 20 milliseconds in duration and up to 5 microvolts in amplitude This suggests that at a certain stage of recovery, more muscle fibres than normal make up the motor unit When the muscle has returned to normal, the action potential becomes the usual normal amplitude

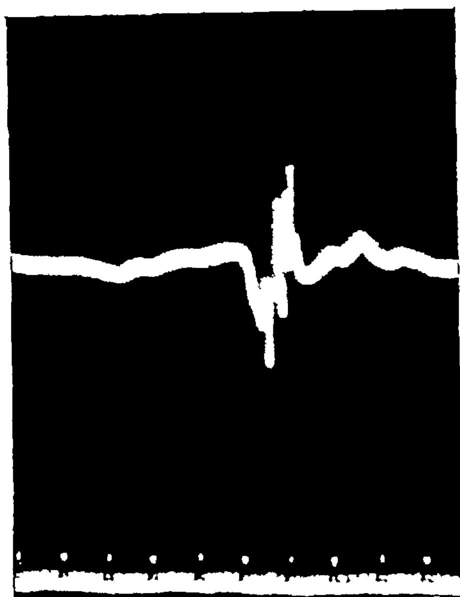


FIG 50 —*Polyphasic action potential typical of nerve regeneration.*

and duration As re-innervation proceeds, so the number as well as the duration of potentials increase

In the very early stages 1 action potential only may be picked up Later, 2 or 3 form a discrete pattern With the re-innervation of a number of motor units, a partial interference pattern is obtained, and finally, in the later stages of recovery, a complete interference pattern Exactly the same changes in the reverse direction are found in a degenerating lesion

The explanation of the polyphasic or complex character of the action potential in degenerating and regenerating lesions is as follows

As the motor unit is recovering, the rate of maturation of the myelin sheaths of the terminal axons will vary from one nerve fibre to another There will thus be considerable differences in conduction time across the various neuro-muscular junctions within the motor unit, resulting in temporal dispersion of the wave-form and accounting for the polyphasic pattern The sound made by these polyphasic potentials is very characteristic, being harsh and crackling in contrast to the smooth booming noise of the normal potential The normal action potential sounds like the sea breaking on the shore, while the polyphasic potential sounds like the more insistent variety of motorcycle engine It is thus seen that a study of the amount and shape of the action potentials will indicate the stage of re-innervation

It is not easy to judge the progress by serial electromyograms as it is with strength duration curves, indeed, the electromyogram is not designed to be used for that type of investigation but it will show the earliest signs of re-innervation even sooner than the strength duration curve It has been found that the detection of a very small polyphasic potential in a peripheral nerve lesion may precede the appearance of a kink on the duration curve by 4–6 weeks, and thus precede clinical signs of recovery by more than 3 months

Spontaneous activity

Spontaneous activity can be either muscle fibre activity as in fibrillation or motor unit activity as in fasciculation

Fasciculation

Fasciculation is the name given to the appearance of spontaneous motor unit activity which can be detected clinically as random contractions in the muscle Some clinicians refer to the fasciculation as fibrillation, but this should be avoided and the name fibrillation reserved for muscle fibre activity, which is, of course, not detectable to the eye, and fasciculation for motor unit activity

On the electromyogram fasciculation appears as irregular normal motor unit action potentials appearing quite spontaneously and discrete in number They are occasionally rather longer in duration than normal and may be polyphasic They are clinically associated with disorders of the anterior horn cells which are degenerating, thus they are seen in motor neurone disease and syringomyelia They are not to be confused with myokymia which is entirely benign and will not be associated with any evidence of lower motor neurone degeneration

When the fasciculation is symptomatic of a degenerative lesion, there will, of course, be all the other signs of denervation

Group discharges

Occasionally, in an irritative lesion of the peripheral nerve, trains of spontaneous motor unit action potentials can be detected They appear in bursts of 4–5 at a time and come quite irregularly They are seen in such conditions as prolapsed intervertebral disc when the disc is irritating the nerve root, and in pressure on nerves by tumours and other swellings

Localization of a lesion by electromyography

The electromyographic picture in lesions at different levels of the lower motor neurone will now be discussed

Lesion in a muscle

In a myopathy, when the disorder is primarily in the muscle fibre and does not affect the nerve, there will be no signs of denervation The response of long duration current will be brisk and the strength duration curve will be normal

On volition small motor unit potentials will appear first and will build up to the full interference pattern on maximum activity There will, however, be a preponderance of very short duration low amplitude action potentials, many of them polyphasic, instead of the normal picture (Fig 51) The interference pattern is normal because whole motor units will not be lost as the lesion is in the muscle fibre itself, but the duration and amplitude of the motor unit action potentials will be small, because individual muscle fibres with the motor unit are destroyed

Lesion in the peripheral axon

Signs of denervation will be present when the lesion is in the peripheral axon as there is nerve involvement

On volition small motor unit action potentials will appear on minimal contraction, but these will not build up into a complete interference pattern because whole motor units will have been lost The action potentials will be polyphasic because muscle fibres within the motor unit have degenerated and will, of course, degenerate at different rates, thus causing temporal dispersion within the unit (Fig 52).

Lesions in the anterior horn cells

The signs of denervation will also be present in lesions in the anterior horn cells.

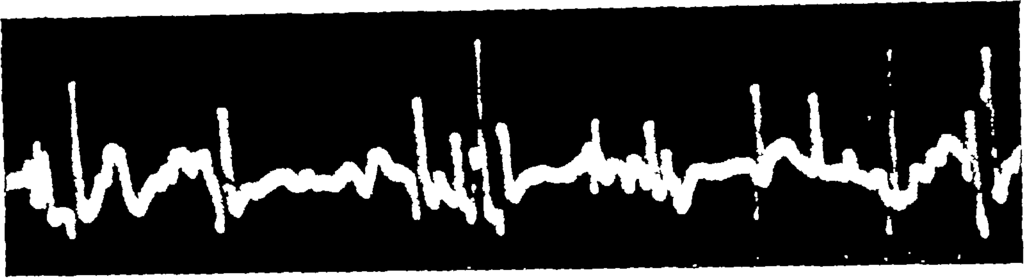


FIG 51 —*Electromyographic picture of a myopathic lesion, note the short duration action potentials*

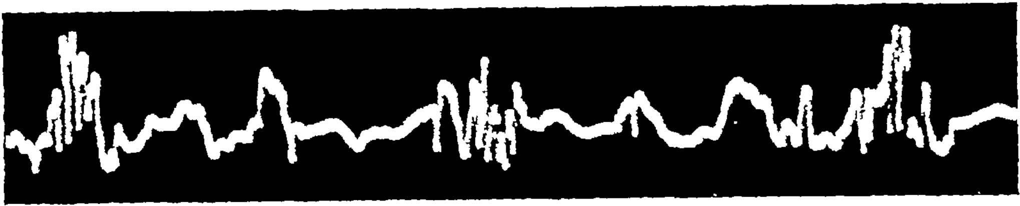


FIG 52 —*Electromyographic picture of a neuropathic lesion, note the highly polyphasic action potentials*

The small anterior horn cells are the most vulnerable in the spinal cord and any lesion in the cord affects them first Consequently, on volition the first action potentials to appear tend to be the large motor unit action potentials which normally do not appear until maximum contraction This early appearance of large potentials is highly characteristic of these particular lesions Furthermore, a full or even partial interference pattern is seldom seen, discrete activity on maximal contraction being the most common picture If the lesion is a progressively degenerative one, fasciculation may be detected

It is thus seen that the electrical signs are distinct in each type of lesion, and their detection is based on sound physiological principles

Signs of denervation

Response to a long duration current is sluggish—a very reliable sign of denervation—and although the response may be more sluggish when the muscle is cold there is, however, no difficulty in distinguishing it from the brisk response of a normal muscle when it is warm As discussed earlier, detection of a sluggish response does not necessarily mean that the whole muscle is denervated, but merely that those fibres being tested are denervated

The strength duration curve shows the response of muscle, that is, a steeply rising parabolic curve with no response to the shorter pulse durations

The rheobase may be lower than normal because denervated muscle tends to be more excitable than normal This is associated with the very much increased excitability of denervated muscle fibres to acetyl choline The value of rheobase is, however, not reliable enough to be taken on its own as an indication of denervation

Chronaxie is long but there is no place for the measurement of chronaxie alone, the full strength duration curve should be plotted

The electromyogram shows fibrillation at rest provided there is no advanced fibrosis and the muscle is not too cold

Of these signs of denervation, the most reliable are the detection of a sluggish response and the characteristic strength duration curve of denervated muscle It quite often happens that these two signs of denervation are present and yet fibrillation is not detected The examiner should guard against disbelieving evidence of a strength duration curve merely because fibrillation was not found

Signs of re-innervation

A response to nerve conduction appears, but this may be a slightly later sign than changes in the strength duration curve and the electromyogram

The earliest sign is a kink in the strength duration curve Later, this kink becomes wider, the curve shifts to the left and the threshold of the curve falls

The rheobase may rise, it may stay the same as during denervation, or it may never change from normal throughout the period of denervation

Usually the chronaxie remains long until advanced re-innervation appears and is thus of no use as an index of re-innervation

The sluggish response may well persist for some time after re-innervation starts Areas may be found in the muscle where the response is brisk, whereas in others it is sluggish

The electromyogram shows the appearance of small polyphasic action potentials, discrete in amount, on volition This may be detected only in one small area of the muscle, usually around the motor point

Fibrillation may be less easy to detect, but this in itself is not a reliable sign of re-innervation

In the earlier stages of re-innervation, rapid fasciculation is often seen in the muscles It is not known why this occurs, but it appears to be a function of the motor end-plate, for it persists despite blocking the peripheral nerve with a local anaesthetic This fasciculation may be picked up by the electromyogram It differs from that associated with the anterior horn cell lesions in that the rate is much faster—up to 4–5 a second—and the amplitude and duration of the action potential is smaller

Signs of progressive degeneration

Serial strength duration curves will show progressive shift to the right, the appearance of kinks, and rise in threshold

The chronaxie becomes longer though not until advanced degeneration has appeared There may be a fall in rheobase but this usually does not appear until later.

Electromyography shows fibrillation becoming more pronounced and a partial interference pattern of polyphasic motor unit action potentials appears, which is gradually replaced by discrete activity when the action potentials become shorter in duration and lower in amplitude

The response to a long duration electrical stimulus becomes sluggish, but this may be a late sign

Nerve conduction is obtained with a much higher threshold of stimulus than on the normal side

The most important of these signs is undoubtedly the early changes in the strength duration curve

Signs of cessation of progressive re-innervation

The strength duration curve ceases to show widening or shift to the left and drop in threshold Comparison of curves at intervals of time shows very little change (Fig 44) The sluggishness or briskness of response is of no consequence in assessing progress

The polyphasic action potentials on the electromyogram become replaced by normal action potentials, and a complete interference pattern of maximum contraction does not appear

Nerve conduction is obtained, but usually with a higher threshold than normal and the gradual drop in threshold with re-innervation is not seen

Signs of partial innervation

The strength duration curve will show a double curve, the kink being small or large according to the degree of innervation

Electromyography will show fibrillation potentials at rest and discrete normal action potentials on volition There will be no polyphasic potentials because this is not a recovering or degenerating lesion, but one in which some fibres are denervated and others are innervated

The response to long duration stimuli may or may not be sluggish The rheobase may be of any value Neither are of assistance in the assessment of partial innervation

The less experienced find difficulty in distinguishing the electrical signs of a recovering lesion from those of a partial lesion This is dependent chiefly on the presence or absence of polyphasic potentials, provided that these findings are always intelligently related to the clinical findings no difficulty should arise.

In patients with hysteria, the detection of a brisk response and a normal strength duration curve is most helpful in establishing the diagnosis An electromyograph is not likely to be of help in such cases as patients will not co-operate to give the volitional activity to show a normal interference pattern

The absence of fibrillation is not a reliable indication of the absence of denervation

SPECIAL CONDITIONS

Polymyositis

In the last 2 years polymyositis has received much publicity It appears that a number of conditions have as a common factor a generalized myopathic response This is shown clinically by generalized wasting of muscle, weakness, a high erythrocyte sedimentation rate, and loss in weight Other signs may include skin rashes when associated with dermatomyositis and high basal metabolic rate when associated with thyrotoxicosis

The main conditions associated with polymyositis are collagen diseases such as scleroderma, lupus erythematosus, and dermatomyositis, carcinoma of the bronchus, and thyrotoxic myopathy

It has recently been found that there are characteristic electrical signs in this condition In general, the signs show that there is a mixed neuropathic and myopathic lesion Thus, there may be scattered areas in the muscle showing a sluggish response, and the strength duration curve may show a kink With the electromyogram there is characteristically a partial or complete interference pattern of

small motor unit action potentials which are often polyphasic and of high frequency with some long duration polyphasic potentials, giving a high-pitched crackling quality to the sound Not all of these signs may be present at one time and not all patients with polymyositis show these changes, but when related to the clinical picture the presence of some, or of all, should be sufficient to make the diagnosis It is clear that much work needs to be done on this fascinating but obscure syndrome

Dystrophia myotonica

Dystrophia myotonica is characterized by myotonia, and the typical associated changes such as fronto-vertical baldness, cataract, testicular atrophy, as well as the typical distribution of muscle wasting, may be present in the patient or his family

Electrically, the strength duration curves are normal and brisk responses are obtained On the electromyogram, however, an absolutely characteristic picture is seen, on the slightest stimulus to the muscle there is a tremendous outburst of very high frequency, very short duration action potentials making a full interference pattern The noise is reminiscent of that of a naval bombardment accompanied by attacks from dive bombers There is no other condition giving this picture

THE USE OF ELECTRICAL METHODS IN LOWER MOTOR NEURONE DISORDERS

It will be seen from this discussion that there is a definite place for the use of electrical investigations for the assessment of lower motor neurone disorders

In peripheral nerve injuries they will (*a*) indicate any anomalies of innervation, (*b*) decide whether a lesion is partial or complete, (*c*) show the earliest signs of re-innervation many weeks before clinical signs appear, (*d*) show the earliest signs of degeneration before obvious clinical signs appear, (*e*) allow an accurate assessment of the extent of the lesion, (*f*) distinguish a neurapraxia from a lesion involving partial or complete degeneration before clinical signs such as wasting and circulatory change are obvious, (*g*) they will show when re-innervation has ceased and will help the surgeon to decide when exploration is advisable, if indicated, and when further recovery without interference is no longer to be expected, (*h*) in poliomyelitis they will give an indication of the extent of damage before clinical signs are seen, for by the second week the strength duration curves will show if there is extensive denervation, and (*i*) they will show when recovery has ceased and thereby help in the planning of rehabilitation and resettlement

If, for example, complete denervation is found in the thenar muscles at the end of the first month after the onset of poliomyelitis, it will be quite clear that no function can be expected in the thumb, and lively splintage or reconstruction operations can be advised at an early age

The differential diagnosis of small muscle wasting of the hand is a notoriously difficult problem Electrical methods will allow the examiner to decide whether the lesion is in the anterior horn cell, such as in motor neurone disease, or in syringomyelia, in the peripheral axon as in peripheral neuritis, or pressure by tumour or other swelling, or in the muscle itself as in myopathy They will also indicate by serial tests if the condition is progressive

Methods to be used for routine investigation

All electrical investigations start with nerve conduction and the plotting of a strength duration curve on a representative muscle of the main groups involved

In a brachial plexus palsy, for example, nerve conduction should be assessed at Erb's point, and at the various places down the arm where the peripheral nerves are accessible Strength duration curves are then plotted on one muscle supplied by each root and nerve, say the deltoid, biceps, triceps, extensor digitorum communis, abductor pollicis brevis, and an interosseus muscle

Finally, electromyography should be performed if the results of such an investigation will add to the information already obtained

With a neurapraxia, for example, if nerve conduction is found and the strength duration curve is normal, there will obviously be no need for electromyography

Similarly, in a peripheral nerve injury, if the strength duration curve shows a kink indicating early nerve degeneration, there is no point in doing electromyography In a patient with wasting of the small muscles of the hand of uncertain cause, the detection of partial denervation by the strength duration curve will not indicate the site of the lesion and electromyography is therefore essential

In brief, nerve conduction indicates if the nerve responds and if there are any anomalies of innervation

The strength duration curve will indicate the presence or absence of denervation and roughly how much denervation, if this is present

The electromyograph will localize the site of the lesion

There are obviously exceptions to these general rules, for example, in a long muscle like the tibialis anterior, the strength duration curve may show complete denervation in the superficial portion, and electromyography may reveal some recovery potentials deep down in the muscle where the strength duration curve cannot reach

Provided that the principles of these investigations are clearly understood, their limitations realized, and the questions phrased in such a way that an unequivocal answer, if possible, can be given, these methods will be found to be of very great value

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CHAPTER 5

THE STIFF HAND

THIS chapter is concerned with the treatment of stiffness of the fingers whether due to fractures, soft-tissue contracture, burns, joint disease, or generalized conditions affecting the hand All the conditions discussed present basically the same problems, that is, restoration of joint function, muscle power and the co-ordinated functions of the hand

FRACTURES

Fractures of the metacarpals

Simple fractures of the metacarpals need an average of 5 weeks' immobilization before allowing removal of the plaster The average time for return to full function on removal of the plaster is 4 weeks All cases of simple fractures seen have attained full function within this period Full-time treatment is not necessary provided the patient uses the hand as much as possible after the plaster is removed There are, however, certain complications in these cases which require specialized treatment

Complications

Adherence of extensor tendons—It is not uncommon for the extensor tendon to become adherent to the callus Mild cases respond well to conservative treatment, which should include oil massage to free the tendon from the callus, and progressive resistance exercises to build up the power of extension Mild degrees of adherence do not limit function and, provided there is a good range of metacarpo-phalangeal joint movement, no further treatment is required

With severe degrees of adherence, however, conservative treatment will not offer a good result It is important to free the tendon from the bone surgically as soon as possible when the adherence is severe If delayed too long, inveterate stiffness of the metacarpo-phalangeal joints develops and there are few more difficult joints to restore to a full range of movement (*see* Case 2, on page 138) After operation, 1–2 weeks' treatment to restore function of the grip and to re-educate the extensor tendon is all that is required

Sudeck's atrophy—The development of Sudeck's atrophy is commoner with metacarpal fractures than with fractures of the phalanges Treatment of this condition has been revolutionized in recent years The principles of early intensive treatment in Sudeck's atrophy have now been accepted, these are discussed in detail on pages 156–157 When associated with fractures of the metacarpal it is important that intensive work should not be started until sound union has occurred Should mobilization start too soon, pain will result and this will keep up the vicious circle of vasomotor instability

Non-union—Non-union is a rare complication Following bone grafting the patient may need many weeks in plaster before union is satisfactory If the patient uses the arm throughout the period in plaster, full function should be obtained within 3–4 weeks after removal of the plaster Full-time treatment is only needed

should there be an undue stiffness of the joints, or if the patient's job demands particularly fine function

Bad position in plaster—Unfortunately patients are still seen who have been badly positioned in the plaster The worst being, of course, with the metacarpo-phalangeal joints in full extension The restoration of joint function in such a situation demands months of intensive skilled treatment, and even then there is only hope of a fair return of function

Treatment is directed to restoring at least one-half the normal range in the metacarpo-phalangeal joints by passive movements many times a day, by stretch splints, and by the wearing of a corrective plaster splint which can be adjusted regularly to increase the pressure towards flexion

Delayed union—Should plaster immobilization be required for longer than 6 weeks, some degree of metacarpo-phalangeal stiffness is likely If the patient is not using the hand vigorously throughout immobilization, stretch splints, resistance exercises and occupational therapy will be needed Once enough movement has been obtained for the patient to carry out his job, further progress can be expected with use

The critical angle of metacarpo-phalangeal flexion is, in our experience, 45 degrees Once this has been achieved further improvement can be expected with normal use

Fractures of the phalanges

Simple fractures of the phalanges require 3–4 weeks' immobilization, and full function should be obtained within 2–3 weeks after mobilization

Dislocations of the interphalangeal joints also require about 3 weeks' immobilization Full function is restored after a few weeks If for any reason active rehabilitation is delayed, some loss of movement inevitably results Except when a patient needs a full range of movement in his job, the function usually returns without treatment Wherever possible plaster immobilization should be avoided by such devices as strapping two fingers together

A number of patients were first seen some 2–3 months after fracture, with considerable limitation of movement of the interphalangeal joints Despite this delay before rehabilitation, function returned very rapidly once intensive treatment was started In several patients as much as 6 months had elapsed since fracture, and there was limitation of movement of 45–60 degrees After 3 weeks of full-time treatment, a full range of movement was restored The average rate of return of movement was found to be 15 degrees a week

Complications

Angulation of the fracture site—This inevitably leads to loss of movement In such a case intensive treatment is advisable Full range of movement cannot be expected, but without treatment surprisingly poor function is the rule The following case history illustrates this point

The patient sustained a fracture of the terminal phalanx, and an infected nail The fracture was immobilized for 3 weeks, and after removal of the plaster the patient was asked to move the hand as much as possible Six months after injury he was admitted to the rehabilitation centre because of permanent stiffness of the terminal interphalangeal joint, which was interfering with many of his activities Passive movements

were 160–135 degrees Active movements, however, were nil After intensive treatment for 3 weeks, comprising re-education of tendon action, progressive occupational therapy with all types of carpentry, and general exercises for grip and hand function, the patient obtained 35 degrees active movement and passive movements increased by 10 degrees extension following the use of night-stretch splints

Adherence of the extensor tendon—This is not uncommon in phalangeal fractures Surgical freeing is rarely undertaken as the results are poor Functional re-education with stretch splints to correct any flexion deformity offers the best prospect of success

Incorrect positioning in the plaster—Bad positioning, lack of use of the hand during immobilization, and immobilizing more than one finger, all lead to avoidable stiffness of the interphalangeal and metacarpo-phalangeal joints

The principles of treatment of fractures of the fingers are never to immobilize more joints than are absolutely necessary, and to encourage maximum use of the unaffected fingers throughout the period of immobilization, hence, the best treatment in such disabilities is, of course, prevention When stiffness has resulted through these means intensive treatment will be required The patient will usually need serial stretch splints, re-education of tendon function and graded occupational therapy

Bennett's fracture

Many cases of Bennett's fracture will achieve a perfect result if treatment is provided early, but some may develop osteoarthritis, and this condition is particularly disabling and painful It is conventionally treated by skin traction in extension, and immobilization may be required for 5–8 weeks Operative fixation is being increasingly used and some cases do well with early movements Throughout any period of immobilization the hand should be used as much as possible Most cases will not require functional rehabilitation, and full range of movement and normal power can be expected 4 weeks after removal of the plaster

When osteoarthritis develops, careful supervised treatment is necessary The patient's first complaints are usually of pain on extremes of movement of the thumb, pain on grip, and when holding tools for long periods Next the hand becomes generally weak so that the patient may drop things and be quite incapable of guiding or manipulating tools Many patients complain of deep-seated grinding which is particularly uncomfortable Once pain has been present for any length of time, a vicious circle sets in of pain—increasing weakness resulting in exposure to further damage of the joint—and more pain

The patient feels acute pain over the joint, the grip will be extremely poor, and the circulation of the hand is often impaired There is often subjective numbness of the thumb, and the skin over the thumb is felt to be colder than the fingers Fig 53 shows the radiological appearance of a typical case

Conservative treatment should be tried first It is always worth while injecting hydrocortisone, 0 5 millilitre (12 5 milligrams), into the joint as a preliminary measure and this may be repeated three times at weekly intervals In the early stages this may relieve the pain sufficiently for the patient to resume his occupation and thus redevelop the power of the thumb muscles It may be necessary, if the patient's job does not involve gripping and turning movements of the thumb, to prescribe occupational therapy and, conversely, if the patient's job is too hard,



FIG 53—*Osteoarthritic changes in the carpo-metacarpal joint following Bennett's fracture*

a lighter form of work must be prescribed, or again, suitable occupational therapy If this treatment does not succeed and the patient continues to complain of increasing pain and weakness of the thumb, some form of splintage is applied The rationale of splinting is to prevent or limit movement in the joint for a few weeks so that the patient can build up the power of the thumb muscles, thus breaking the vicious circle of pain—weakness—pain

If the condition is severe it is advisable to immobilize the thumb completely so that all movement is prevented

In milder cases or in severe cases where complete immobility prevents the patient doing his job, modified immobilization can be used by providing a leather splint, with or without Perspex reinforcement on the extensor aspect Within a few days the pain will be materially reduced, certainly enough to allow the patient to use the hand in moderately hard activities It is important not to stop immobilization too soon It has been found that if immobilization is removed before the grip by measurement is over one-half that of the normal side the patient will certainly relapse The test as to whether the patient is ready for mobility is the power of the stabilizing muscles

Where pain is an outstanding feature, a combination of intra-articular hydrocortisone injections and splintage is worthwhile Additional measures can be used

to help relieve the pain, a wax bath to the patient's hand before occupational therapy is of value not only in relieving the pain, but for its beneficial effect on the impaired circulation In severe cases the splintage may be worn for 3–4 months before the pain is completely relieved Patients often find it useful to keep their splint for many months, or even years, wearing it while undertaking heavy work Should this treatment fail, then operative measures are the only ones likely to offer permanent relief of the pain, this will mean arthrodesis or excision of the trapezium

Those patients who are constantly using their hand for heavy tasks will benefit more by arthrodesis When immobilization is stopped after this operation, most patients will require formal rehabilitation, because they will have had, in almost all cases, many months of severe pain and weakness of the hand, therefore, they will require re-education in activities of the hand as well as improvement in gross muscle power The average time for restoring maximum function after removal of the plaster following arthrodesis is 6 weeks The length of time bears a direct relation to the time in plaster as well as to how long the patient had symptoms before operation

Fig 54 shows the splint used for partial immobilization of the carpo-metacarpal joint in osteoarthritis The manufacture of the splint is described elsewhere

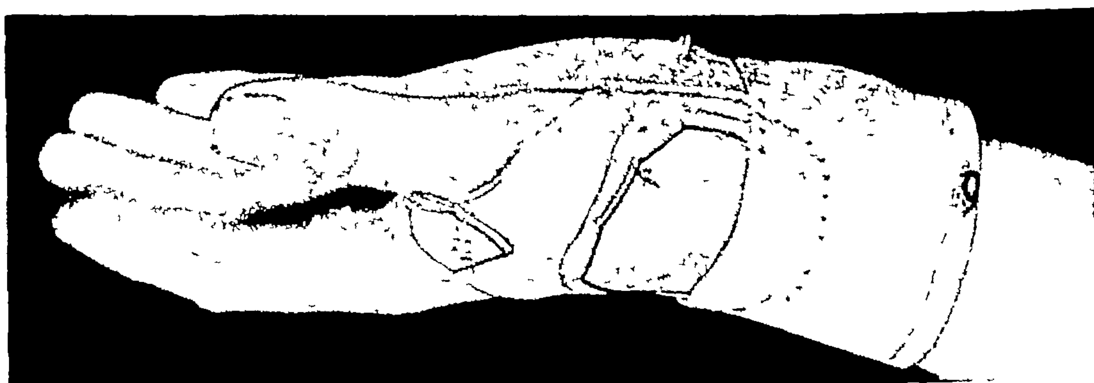


FIG 54 —*Splint used in cases of osteoarthritis of the carpo-metacarpal joint*

Fracture of the sesamoid bone of the thumb

This must be a rare condition Fig 55 shows a radiograph of a patient who sustained such an injury when he slipped and fell on the thumb

He was immobilized for 3 weeks in plaster Following its removal he was admitted to the rehabilitation centre At this stage the thumb was very tender and stiff Grip was 7 lb compared with 13 lb on the normal side

The fracture had not united, intensive rehabilitation by exercises and occupational therapy was therefore prescribed to restore full function

He was discharged with no pain and full power and function 1 month later

DUPUYTREN'S CONTRACTURE

Description -

Skoog (1948) gave the incidence of Dupuytren's contracture as 1 5 per cent In his series of 50 patients, 18 per cent had involvement of the plantar fascia as well



FIG 55—*Radiological appearance of fractured sesamoid of the thumb*

as the hands It is well known that this condition of contracture of the fascia of the palm is also seen in the plantar fascia The feet, however, only require treatment if the condition is causing pain

Conversely, there are very few patients who, once Dupuytren's contracture is established in the hand, do not require surgical treatment The length of time the patient has suffered from the onset of symptoms before seeking advice varies so much on the disability it causes him and its rate of development Furthermore, the intelligence of the patient is a considerable factor One is constantly amazed to see how patients will put up with appalling degrees of disability before they come for advice, and in several cases the only treatment that could be offered was amputation of the little finger which was flexed completely into the palm and beyond any aid

In our series the time from onset of contracture to operation varied from 2 months to 10 years, with an average time of 4 years In only 7 per cent was there a family history In 20 per cent there was a history of some trauma, common precipitating factors being blows sustained in football games, constant digging and crush injuries of the hand Very few patients were seen who had had the condition following repeated trauma in the palm from a tool, such as a drill or a screwdriver

In 50 per cent the left hand alone was affected, in 20 per cent the right hand alone, and in 30 per cent both hands were affected

Treatment

If the disability is slight and the condition progressing only very slowly, surgery

is not indicated Hydrocortisone has been used by some workers, notably Baxter and his colleagues (1952), but they were unable to arrive at any definite conclusions except to point out that this treatment does not replace surgery It is important to advise the patient who presents with a very early Dupuytren's contracture to report back if and when the disability increases, and for this reason it is advisable to follow up such patients at regular intervals It is generally agreed among surgeons with extensive experience of this condition that total excision of the palmar fascia is the only means of treatment

Healing of the operative scar may be slow due to poor circulation after months or years of fibrosis, and the disability when active rehabilitation starts may not be much less than it was before correction However, even with skin grafting, when the patient will have had the condition for a long time, permanent contraction of the fingers must be overcome, and the deep fibrosis resolved by physiotherapy The average time from operation to the commencement of *intensive* rehabilitation is 5 weeks In some patients, who have had the condition for many years and in whom the skin is of poor quality, the surgical scar may not heal fully for 4–5 weeks During this stage saline solution soaks should be given and the patient encouraged in active exercise both in the saline bath and with the physiotherapist The object of these saline baths is to reduce the scaling, clean the skin, relieve pain and thus encourage the patient to exercise the hand Under no circumstances must heat be used as the recently and thinly dissected skin of the palm is liable to be necrosed by heat The physiotherapist must encourage active flexion at the metacarpo-phalangeal and interphalangeal joints, each joint being supported in turn Between treatment sessions a tulle gras dressing is worn Light occupational therapy is essential but the patient must wear his dressing It may be advisable in the early stages for the patient to have the arm elevated in a sling if there is the slightest sign of oedema which, if allowed to persist for even 2 days, will result in further fibrosis The deformity of the hand at this stage is normally 45 degrees flexion of the proximal interphalangeal joint, and a slight—maybe 10 degrees—flexion deformity at the terminal interphalangeal joint In a very severe case the metacarpo-phalangeal joint may also be held in flexion, sometimes as much as 55 degrees (at 125 degrees) There is unlikely to be any movement in the terminal interphalangeal joint or proximal interphalangeal joint In those patients where flexor sheaths are extensively affected, little or no active flexion can be expected to return Full-time intensive treatment is required for a period on average of 6 weeks after operation, except in the severe cases who may need up to 5 months' treatment

In about 25 per cent of patients the little finger remains solid and in 45 degrees of flexion (135 degrees) at the proximal interphalangeal joint, no active movement returning This deformity is particularly liable to be seen in patients with a long history in whom there has been some complication at operation, such as a haematoma Provided the flexion deformity is not severe, function can be excellent If it interferes with any of the patient's activities, amputation is the best treatment

The stiff little finger so often seen in severe cases is due to diffusion of the affection from digital fasciculi of the palmar aponeurosis invading the anterior capsule where the fasciculi fuse with it around the free tendons

The principles of treatment, once the scarring has healed, are to tackle the fibrosis by increasing the vigorous oil massage, to stretch the contracted soft tissue

by graduated plaster stretch splints, to restore, where possible, the function of the remaining flexors and the extensors and to redevelop the grip and general function of the hand

For the first few days after the scar has healed, oil massage is given only twice a day, and only lightly By the end of the first week, the massage can become vigorous and be given 4 times a day In those cases where the flexion deformity is not being rapidly overcome by this means, serial stretch splints should be started The stretch is increased as the deformity responds and the patient must wear the splint at night Re-education of the long flexor action and long extensor action is given at every treatment session as described in Chapter 2 All the various exercises and games described there are appropriate to these patients

The fingers must be stretched not only in flexion but also in abduction, adduction, and rotation of the metacarpal heads where so much tightness exists It should not be forgotten that as the fingers may have been flexed for months or even years, the extensors are involved and require re-education It must not be expected, though, that more than a few degrees controlled extension at each joint will return, but this need be no bar to good function The progression of treatment varies from case to case

The underlying principle of all treatment in patients with Dupuytren's contracture is to maintain the correction of the soft-tissue deformity obtained at each treatment session by the stretch splint The physiotherapist will be able to judge by the amount of correction being obtained each day whether or not progress can be speeded up The careful measurement at weekly intervals of flexion deformity will also indicate whether treatment needs to be intensified An improvement in extension of 5 degrees or more each week is satisfactory progress

The regime for a Dupuytren's contracture, then, comprises first a wax bath to soften the skin, promote circulation and reduce pain, which is bound to result from the subsequent stretches Next, passive movements at all joints, then stretches, the scarred tissue being rolled, stretched and pulled, followed by re-education of tendon function at each joint, finally, group action of flexors, extensors and grip

During the exercise session the physiotherapist grips the hand with her own hand moulding round the metacarpo-phalangeal and interphalangeal joints With the patient's palm down, the physiotherapist puts her fingers under the proximal phalanges, her hand on the dorsum of the patient's hand and stretches the whole hand up Then with the wrist down on the table, a full active and passive stretch is attempted with the wrist and fingers being stretched

Patients are encouraged to carry tennis balls to stretch their tendons during the day

Physiotherapy must be repeated as often as possible, preferably 4 times a day

Patients who have 1 hour's treatment 2–3 times a week do not do well There is no hope of mastering the deformity and retaining progress at each session if patients come so seldom

Case histories

The following case histories illustrate the points described above

Case 1 This patient had a recurrence of Dupuytren's contracture in the right hand 4 years after operation This was removed and the recurrent contracture of the palmar fascia also removed Three weeks after operation the patient presented with a very

thick scar 1 inch proximal to the metacarpal-phalangeal joint of the little finger and 2 inches across It was 10 days more before the scar healed fully At this stage treatment comprised intensive oil massage 4 times a day for 30 minutes at each session combined with stretch splints, active exercises and games Three weeks after commencement of rehabilitation he returned to work with a full range of movement and function at all joints

Case 2 This patient developed Dupuytren's contracture following a long period of digging as a prisoner of war He had a 10-year history, both hands and both feet being affected Two months after operation he presented with an unhealed very adherent scar, the metacarpo-phalangeal joint of the index finger was held in 60 degrees of flexion (at 120 degrees) while the medialis, the ring and the little fingers were held in 55 degrees of flexion (at 125 degrees)

There was no active flexion in any joint of the ring or little fingers and there was no grip

Saline solution soaks were given until the scar healed, when a full programme of oil massage 4 times a day, stretch splinting, exercises and games were carried out

After 3 months the flexion deformity at the metacarpo-phalangeal joints was completely overcome The grip was excellent but there was no return of flexor action in the interphalangeal joints of the ring or little fingers The rate of return of metacarpo-phalangeal extension was 8 degrees a week Fig 56 *a*, *b* and *c* illustrates the progress of this patient

Case 3 This patient had a 3½-year history before operation, the first symptom being the development of knuckle pads There was no family history and no history of trauma The palmar fascia and the ring finger were affected in both hands Six weeks after operation the scar had healed and intensive rehabilitation was started The little fingers were held in 45 degrees of flexion (at 135 degrees) at the proximal interphalangeal joints, and the ring fingers in 50 degrees of flexion (at 130 degrees) There was a deep thick scar 1¼ inches proximal to the metacarpo-phalangeal joints After 3 weeks' intensive treatment, full function and full movement were restored to all joints

Case 4 This patient sought advice 10 years after being hit by a cricket ball in the palm of his hand There had been one operation which resulted in a complete cure, but in the months before the second operation he noticed gradually increasing flexion of the little finger until it was almost completely bent into the palm One month after operation the patient started active rehabilitation There was a thick scar along the whole of the ulnar aspect of the palm, measurements of the ring and little fingers were at the terminal interphalangeal joint 130–125 degrees, proximal interphalangeal joint 150–148 degrees, and metacarpo-phalangeal joint 5 degrees of hyperextension to 30 degrees of flexion (185–150 degrees), the grip was non-existent After 1 month's intensive treatment, full movement and full flexion were restored

TREATMENT OF BURNS OF THE HAND

The late effects of burns, scarring and contracture of the soft tissues, are the causes of disability After a burn of some severity, surgical treatment will be almost inevitable, contracted webs and thickened scars need removal, and skin grafts are often required with or without Z-plasty lengthening procedures

The general principles in the rehabilitation of the burnt hand are the same whatever the extent or degree of the burn The rate of progress depends entirely on the severity and extent of the burn, and on associated disabilities such as infection, burns elsewhere in the body and systemic reactions The principles of treatment

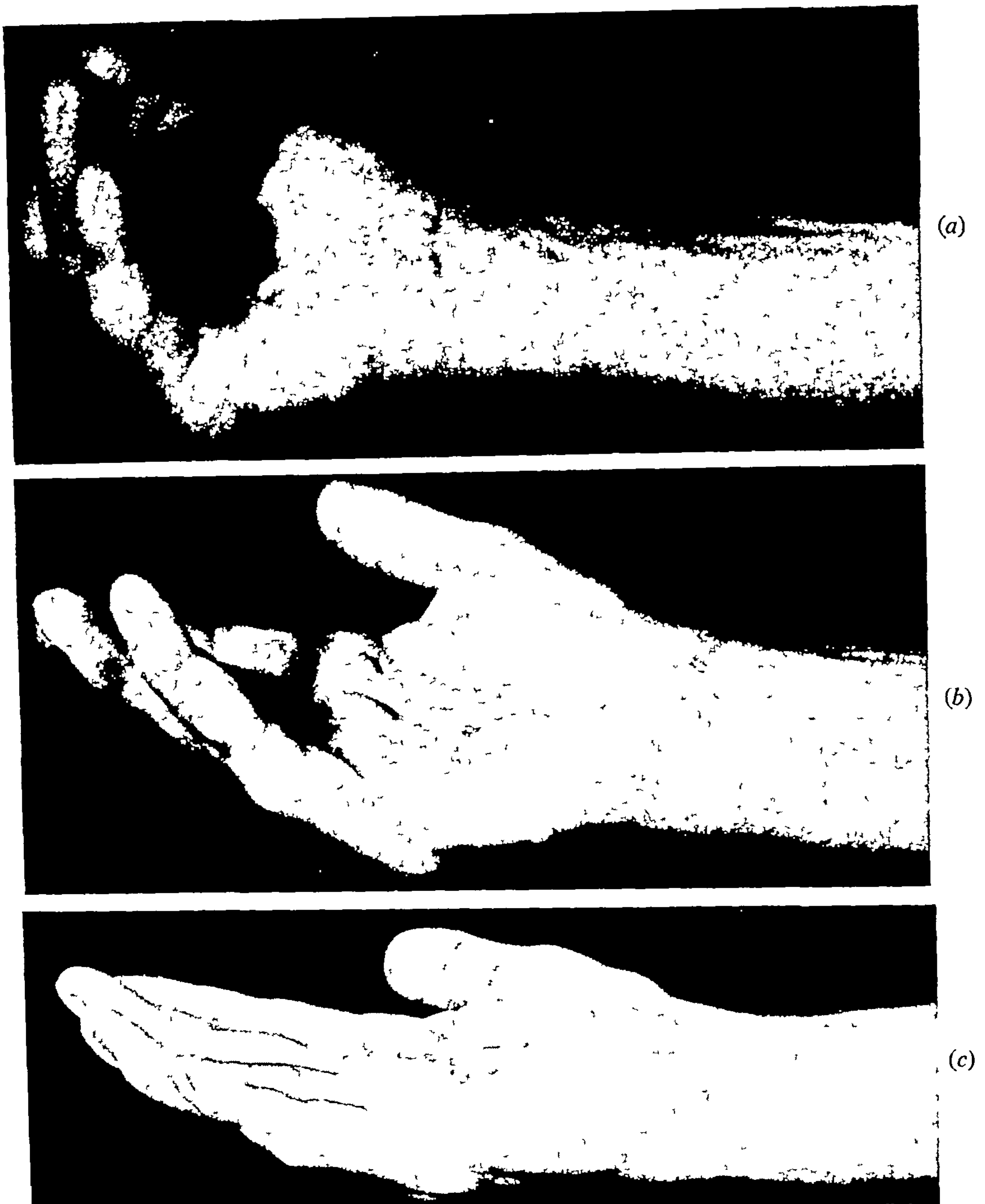


FIG 56—*Progress in a patient* (*Case 2, page* 138) *with Dupuytren's contracture* (a) *Two months after surgery* (b) *Six weeks after commencing rehabilitation* (c) *On discharge after 3 months' rehabilitation*

are to correct soft-tissue contracture by oil massage and stretch splinting when necessary, to improve the circulation of the hand, to re-educate tendon function, and to restore grip

Burns of the fingers

When there is any skin loss a graft is applied, either a dorsal flap to cover an

exposed flexor tendon or a Tiersch graft Active treatment starts 1 month after operation Four to eight weeks are required for full function to return after skin grafting Most patients obtain an almost full range of movement at the interphalangeal joints and full function of the hand, provided there are no complications such as infection or gross scarring Even though the prognosis is so good, it is advisable for patients to have full-time treatment, at any rate for 3–4 weeks after active treatment is permitted There is some danger of soft-tissue contracture limiting movement during this stage Care should be taken to see that the graft is free and does not become adherent to the deep structures Should this appear likely to occur, oil massage is given twice a day Stretch splints are not required in the rehabilitation of recently grafted fingers Any form of heat such as radiant heat, infra-red or short-wave is contra-indicated after skin grafting for the fresh skin is very vulnerable and dies if subjected to heat

Generalized burns of the hands

When the hand is burnt to a severe extent, almost all of the hand is affected It is impossible to generalize on the manner of presentation as so much depends on the severity, the local and general complications, and the extent of the burns The consequences are the same whatever the circumstances soft tissues contract, the circulation is impaired, the movement of tendons is interfered with, and the general function of the hand is gravely affected In no other condition does severe and possibly permanent disability follow so quickly after injury

The surgical treatment is almost invariably extensive grafting, the details of which are not relevant in this work

Rehabilitation starts as soon as the grafts have taken and the scars have healed Elevation of the limb in the early stages is vital, and elevation for part or whole of the day may be necessary in the early weeks of rehabilitation It is essential that no oedema should be allowed to collect in the hand after operation—there is sufficient fibrosis present without adding to it Moreover, function must be preserved where possible—unaffected parts of the limb should be kept active The satisfactory rehabilitation of the severely burnt hand requires the closest liaison between the plastic surgeon and the rehabilitation department Throughout treatment, serial operations may be necessary and their timing may be a matter of critical importance

Case histories

The following case histories of 2 patients with severely burnt hands will illustrate the principles of treatment

Case 1 This patient sustained burns of both hands, legs, face and shoulders in an aircraft crash, the whole of the dorsal surface of the hand and fingers was severely burnt Stamp grafts were applied 5 days and 12 days after injury, and the patient was admitted to the rehabilitation centre 2 months after the accident At this stage (Fig 57 *a*, *b* and *c*) he presented with a rock-like hand and scarring on the whole of the dorsal surface of the left hand There was no active flexion in any of the fingers and passive movements amounted to only a few degrees Palmar flexion was 10 degrees There were several areas over the back of all the fingers which were slow to heal

The first objective was to encourage the patient to use the hand and thus improve its circulation to promote healing preparatory to the next operation

Oil massage, 4 times a day, combined with progressive resistance exercises for the



FIG 57 —*Burns of the hand* (*Case 1, page* 140) (a) *Dorsal appearance* (b) *Maximum finger flexion possible 2 months after accident* (c) *Result after 25 weeks' treatment*

fingers, together with general exercises and games for hand function, were given for 6 weeks At this stage the circulation was much improved and there was 15 degrees (180–165 degrees) movement at the metacarpo-phalangeal joints Further improvement,

however, was prevented by the continual breaking down of the wounds on the dorsal surface of the fingers

The scars on the back of the hand were then excised and thin skin grafts applied The patient returned to the rehabilitation centre 5 weeks later, and at this stage movements were as tabulated below

TABLE I

FINGER MOVEMENTS (DEGREES) OF CASE 1

Finger	*Metacarpo-phalangeal joint*	*Proximal interphalangeal joint*	*Distal interphalangeal joint*
Index	180–150	180–150	180–130
Middle	180–130	180–135	180–90
Ring	180–150	180–130	180–110
Little	180–160	180–170	180–110

There was 30 degrees of flexion at the interphalangeal joint of the thumb, and the thumb could be opposed as far as the ulnar border of the middle finger Two weeks later stretch splints were started in earnest to encourage flexion, particularly in the fifth finger Nineteen weeks after the accident, the webs between the thumb and index finger and the medialis and ring fingers were excised and Tiersch grafts applied When seen 17 days later, and after 3 weeks' further intensive treatment full function was restored except for the extremes of opposition of the thumb (Fig 57 *c*)

This patient thus required 25 weeks' continuous treatment for the severe burns of the hand He was, however, able to return to full duty in his trade of operations clerk where good free movement of the hand was essential

The principle of full-time intensive treatment dovetailing with the periodic operations required is calculated to give the best result Only such a programme can keep pace with and overtake the relentless soft-tissue contractures that are the menace of the burnt hand

Case 2 This patient sustained third-degree burns of both hands when the lorry he was driving caught fire The arms were burnt from the elbow to the finger-tips on both sides, mainly on the palmar surface Extensive skin grafting was carried out, and 7 months after the accident he was admitted to the rehabilitation centre On the left hand there were no movements at any of the interphalangeal joints, and the metacarpophalangeal joints were held in 30 degrees of flexion (at 150 degrees) The right hand was less seriously affected but there was no palmar flexion and no movement at either interphalangeal joints of the ring finger In both hands there was very adherent and tough scarring, the left hand being considerably worse than the right After 2 weeks of intensive treatment, involving oil massage 6 times a day and the usual treatment for burns as described earlier, there was 20 degrees active movement in the interphalangeal joints of the left hand

Five months later there was 60 degrees of movement (180–120 degrees) at all the proximal interphalangeal joints of the left hand There was 15 degrees of movement at the terminal interphalangeal joint and 5 degrees at the proximal interphalangeal joint of the ring finger There was 10 degrees of movement at the interphalangeal joints of the other fingers In the right hand there was almost perfect function It was thus 1 year before this patient was able to return to work in a full-time capacity The important point in this case is that after extensive burns of the palmar surface of both hands, resulting in a great deal of skin loss, the patient was able to return to full work However expert the surgery, good results cannot be expected unless the operation is followed by intensive, graded and full-time rehabilitation

SEPTIC FINGERS

General

Formal rehabilitation is necessary when infection occurs in the palmar space, the tendon sheaths, the web space, or when a generalized cellulitis develops When incisions are made to release pus, and when antibiotic treatment is started early, there is little or no fibrosis and subsequent scarring Active rehabilitation can therefore start within 4–6 weeks The average time for the restoration of full function is 2–3 weeks When, however, early control of infection is not obtained results as judged by range of movement of the fingers may be poor

If there has been extensive infection which has been slow to resolve, and several incisions have had to be made, healing may be slow Considerable pain is caused by active exercise in the early stages of rehabilitation when the necrosed and scarred tissues are present This inevitably leads to limitation of movement The problem becomes that of coaxing fibrotic soft tissues into yielding by deep massage and long-continued stretch splinting

Infections of the palmar space

Unless very extensive and resistant to antibiotic treatment palmar space infections do well As the general function of the hand and particularly the power of grip suffers considerably after these infections, it is advisable for the patient to have full-time treatment once the infection has resolved and all incisions healed Although only 2 weeks' treatment is usually required for full function to be obtained, without it the patient may not regain full power of grip as the soft tissues contract extensively in the early days after such infections It is particularly important for patients to receive rehabilitation when several incisions have been made, when an extensive area of skin has been lost or in long-standing scarring of the palm

Finger infections

Simple infections do not require rehabilitation, but when the tendon sheath is affected, loss of movement and scarring are sufficiently severe for rehabilitation to be essential Active exercise should be started as soon as the infection is completely resolved and all incisions healed This may be as long as 3 weeks after infection

At this stage the interphalangeal joints may have only 50 per cent of the normal range of movement, and when the tendon sheath has been severely damaged there may be no movement at all In these cases tendon grafting is advisable unless the soft tissues are so severely damaged that the graft would not take In such a case arthrodesis of the interphalangeal joint in the functional position, or amputation, if the finger gets in the way, is the best course If the tendon sheath is not too badly damaged and the flexor tendon not affected, 2–3 weeks of rehabilitation will result in full function For the first week of active treatment, unresisted exercises together with light occupational therapy and light games should be given By 6 weeks after the infection has resolved, moderately heavy occupational therapy and resistance exercises in the physiotherapy department can be started

If there is any sign of impaired circulation developing during treatment, resistance should be very carefully graded and no form of heat be used When there has been much scarring, no more than a few degrees movement at the terminal

interphalangeal joint can be expected Provided that there is a reasonable range (45 degrees or more at the proximal interphalangeal joint), general function will be good The lack of movement at the terminal joint need not be a disability It takes from 6 to 8 weeks for full function to be restored in such cases

Web-space infections

By 2 weeks after incision of web-space infections, patients are ready for rehabilitation In all except the mildest cases 2–3 weeks of intensive rehabilitation are necessary as there is a tendency for the metacarpo-phalangeal joints to go into flexion following scarring Power of grip is also considerably diminished

General exercises, occupational therapy to encourage grip, and resisted extension exercises to metacarpo-phalangeal and interphalangeal joints restore full function

Cellulitis

One cannot generalize in this condition as the disability depends on the extent of infection and the success of antibiotic treatment, thus the problems vary greatly in individual cases Rehabilitation is always required

The principles of treatment are those underlying any infection in the hand—stretching of fibrosis by oil massage and serial splints, individual re-education of each tendon, restoration of passive joint movements and redevelopment of grip and general function

AMPUTATIONS

Phalanges

In the straightforward case of phalangeal amputation, the patient should be ready to start intensive rehabilitation by 4 weeks following the operation The average time for the patient to achieve full function at our rehabilitation centre was 4 weeks

The problems in rehabilitation in such cases are to encourage the patient to use the affected hand and to restore the power of grip Restoration of a full range of movements to the metacarpo-phalangeal joint or to the proximal interphalangeal joint, if present, is not difficult The power of grip is extraordinarily weak and may take as long as 6 weeks to restore Patients are singularly reluctant to use the affected hand, partly because the stump may be tender and partly for psychological reasons—many patients develop a dislike of the hand This is particularly true if the start of intensive rehabilitation is held up for any reason It has been found that if the wound is slow to heal, or the patient cannot begin intensive treatment by 4 weeks after amputation at the most, full function may be delayed by as much as 6 weeks, the patient thus requires 10 weeks or more at the rehabilitation centre

It seems that unless the patient can quickly be encouraged to use his hand normally, the fact of an amputation becomes a more serious disability to him than one would imagine, and he finds it difficult to use the hand at all normally Sometimes the stump is tender and the slightest tap or jar may cause pain down the phantom finger This is less often a problem in rehabilitation of phalangeal amputations than in metacarpal amputations where tenderness of the stump is very frequent When it is present, however, the pain is a severe bar to recovery of full function because the patient is loath to use the hand for anything at all heavy owing to the pain

The first object of treatment, therefore, must be to abolish the pain By far the most effective method is repeated tapping of the stump At the first interview the doctor very gently taps with the pulp of his index finger on the tender stump The movement should be so light that the stump is only just tapped, but even this may cause considerable pain and apprehension The patient is encouraged to tap the stump himself for 5 minutes every hour of the day, at first very gently, and later progressing to more and more vigorous tapping By the third day he should be able to tap fairly firmly, and by the end of a week the pain in almost every case has been completely abolished As patients are very apprehensive and loath to carry out this treatment, it is explained to them that tapping encourages the formation of a fibrous protection to the bare nerve endings, and that the more they persevere the sooner this protection will be produced The fact that this explanation is not physiologically sound is of no importance to the practical result, patients must be given a reason for carrying out the exercise

Some time should be spent with the patient at the first interview, tapping the stump very gently whilst distracting the patient's attention by engaging him in conversation, one often finds that by the end of the interview the patient is tolerating considerably firmer tapping than at the start and this will convince him that regular tapping is worthwhile

The principles of restoration of function of the hand are simply those of restoring the power of grip, which is done by encouraging the patient to use the hand in gradually more intensive occupations Basketry is a good craft with which to start the patient As soon as the stump is no longer tender and the patient has lost his acute consciousness of having lost part of his finger, he can progress to carpentry, and later to metal work At the same time the physiotherapist encourages independent action of all the fingers and the various games and exercises

Metacarpal amputation

When a metacarpal is amputated the structure of the palm is directly affected and power of grip and general function of the hand are seriously impaired The stump or scar is almost always acutely tender and requires the tapping treatment described above

The principles of treatment do not differ from those discussed under phalangeal amputations, the power of grip is more difficult to restore, and the average time under rehabilitation is about double that for amputations of the phalanges The average time in our series was 7 weeks from the start of rehabilitation to return to work

The patient should not be discharged until it is quite certain that he is not sparing the hand and that he intends to use it for all activities Complicating factors include associated tendon lesions and fractures These are troublesome in so far as they delay the onset of intensive rehabilitation and cause pain or limitation of movement such that the patient is unable to work hard and restore the grip

Case histories

Case 1 This patient sustained traumatic amputation through the proximal phalanges of the left ring and middle fingers when chopping wood; both tendons of the little finger were severed at the same time Two months after the accident he was admitted to the rehabilitation centre with a very weak hand and very tender stumps After 6 weeks' full-time treatment, including tapping, progressive occupational therapy,

passive movements to the little finger and progressive resistance exercises for the hand, he was returned to work with a full passive range of the joints of the little finger At this stage the patient declined tendon grafting, 6 months later he decided to have the tendon grafted and was admitted for pre-operative treatment as he had lost a considerable part of his passive range At this time there was 20 degrees of movement at the terminal interphalangeal joint, and only 20 degrees flexion at the metacarpo-phalangeal joints of the middle and ring fingers This was due to his inability to use the fifth finger in activities of the hand which was reflected in the weakness of the grip—being only one-third of the normal side Fifty-five days after tendon grafting there was 20 degrees movement at the terminal interphalangeal joint, 50 degrees at the proximal interphalangeal joint, full range at all metacarpo-phalangeal joints, and almost normal grip

Case 2 This patient sustained amputation to the distal phalanx of the middle finger and fractures of the proximal and distal phalanges of the thumb and fracture of the distal phalanx of the index finger following an explosion of sodium chlorate in his hand

The index finger was skin grafted and 3 weeks later intensive rehabilitation was started After three weeks' treatment he returned to work with excellent function, the only limitation being in the index finger, movements of the terminal interphalangeal joints being 135–100 degrees and the proximal interphalangeal joint 150–70 degrees

Case 3 This patient sustained severe lacerations of the hand when he fell on a glass tumbler The index and middle fingers were avulsed through the middle phalanges Two months later he was admitted to the rehabilitation centre, there being no movement in either joint of the ring finger due to rupture of the extensor tendon and contracture of the flexor tendon The tenderness of the stumps was soon eased, and after a month's treatment he was discharged with good power and function but with the terminal interphalangeal joint of the ring finger held in 70 degrees flexion (at 110 degrees) This was a satisfactory functional position for his job as a metal worker and, therefore, further treatment was not considered to be worthwhile.

Case 4 This patient had amputation performed through the metacarpal of the ring and little fingers following a failed tendon graft, the little finger being acutely flexed and in the way Three months after the amputation his function on admission to the rehabilitation centre was very poor, mainly due to the extremely painful stump and the patient's great apprehension Tapping was started immediately together with wax baths, oil massage to the scarring in the palm in line with the flexors of the little finger, and graded occupational therapy After 1 month's treatment he returned to full duty as a rifleman

Case 5 This case history illustrates the good function that can be obtained after amputation, provided intensive treatment is given This patient sustained an injury with a guillotine bread slicer resulting in avulsion through the middle phalanx of index, avulsion through proximal interphalangeal joint of middle finger, and severe laceration to bone, opening the terminal interphalangeal joint of the ring finger

Skin grafts were applied to the ring finger 9 days later

Six weeks later he was admitted to the rehabilitation centre The terminal interphalangeal joint of the ring finger was held at 110 degrees The extensor tendon was not working, the grip was poor and circulation sluggish (Fig 58)

One month later function was sufficiently good for the patient to return to his clerical duties There was almost as strong a grip as on the normal side and the circulation was normal

The overriding factor in our experience has been to encourage the patient to use the hand and to forget that he has lost some part of it This may be difficult in the early stages for two reasons First, the stump may be so painful that the

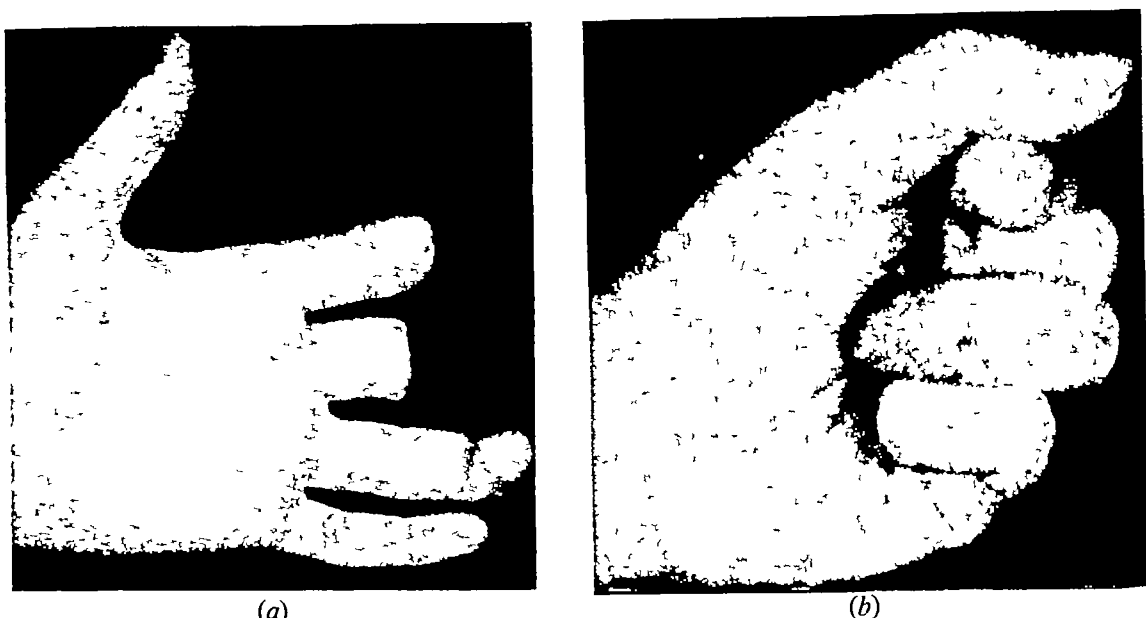


FIG 58 —*Amputation of the middle and distal phalanges of the index and middle fingers of the left hand* (a) *Six weeks after injury at start of rehabilitation* (b) *End-result after 4 weeks of treatment, showing maximum flexion*

slightest movement or contact with tools causes acute pain, secondly, the psychological effect of losing part of the finger or hand may result in the feeling that he will never be able to use his hand again properly, consequently the patient makes no effort to regain function

In the first instance regular tapping will abolish the pain In the second instance the patient must be encouraged throughout treatment by all the members of the rehabilitation team to use his hand as much as possible, and be made to realize that the disability is only slight and will in no way affect function By far the best way of doing this is for the patient to see for himself that he can use his hand, and it is here that the services of the occupational therapy department play an essential part

ARTHRITIS

There are three main arthritic conditions which affect the fingers and call for rehabilitation They are infective arthritis, rheumatoid arthritis and osteoarthritis The problems of the rheumatoid hand are dealt with separately (Chapter 6)

Infective arthritis, if treated early with antibiotics, may result in little or no disability When it becomes a disability it is due to the permanent limitation of movement in the joint, consequent on articular damage Attempts by conservative measures to increase the range of movement through, for example, stretch splints, passive movements, or manipulation under anaesthesia hardly ever produce any worthwhile increase in range It is only when the limitation of movement in a joint is extra-articular—for example, a capsular shortening—that such measures are successful

The principles of rehabilitation are, therefore, those of restoring maximum function in the hand by encouraging the patient to use it, and by developing the power of grip

If the finger gets in the way, preventing the patient from handling tools, amputation should be considered A short course of intensive rehabilitation is well worthwhile before amputation to restore power and encourage normal use of the hand as much as possible This will make subsequent rehabilitation after amputation easier and quicker

Occasionally, digital arthroplasty is used, Carroll and Taber (1954) suggested the following criteria for this operation

(1) The deformity must be such that the joint is in an awkward position
(2) The tendon must be intact
(3) The patient must be fully co-operative

In their experience, removal of the distal third of the proximal phalanx is the correct procedure for affections of the proximal interphalangeal joint They counsel against removing any of the base of the middle phalanx Traction is given for 6 weeks and then full-scale rehabilitation is started In a series of 16 patients, 9 had fair results and 5 poor after this operation The results of this operation in our series have been much the same as those of Carroll and Taber For the operation to be considered at all it is obvious that there must be considerable disability in the hand As this is very likely to involve capsular thickening, soft-tissue scarring, and possible long-standing weakness and disuse of the hand, results cannot be expected to be outstanding Arthroplasty for the terminal interphalangeal joint is never considered, as arthrodesis in the functional position offers a far better result Recovery of movement after arthroplasty may be disappointing, but even if only 20 degrees movement is obtained this is often sufficient to improve the function of the hand, particularly in regaining the power of grip

When treating any condition where intra-articular adhesions limit joint movement, stretching is not of value and, indeed, passive therapy tends to cause stiffness, pain and thickening of the soft tissues

Osteoarthritis

The commonest joint to be affected by osteoarthritis is the carpo-metacarpal joint of the thumb, following Bennett's fracture This is dealt with fully on pages 132–3 Occasionally, the interphalangeal joints of the fingers are affected by osteoarthritis, particularly in heavy manual workers, or after intra-articular fractures Injections of 0 5 millilitre (12 5 milligrams) of hydrocortisone should be given as a first measure and be repeated up to 3 injections If the first injection is unsuccessful some form of splinting to the finger to reduce movement and encourage redevelopment of muscle power is tried Wax baths are often effective in reducing pain and it is a good policy to encourage the patient to give himself either a wax bath or a soak in warm water once or twice a day at home For osteoarthritis, consequent on intra-articular fractures, arthrodesis, arthroplasty or amputation may be required according to the patient's job

CRUSH INJURIES

General

Perhaps the most disabling and difficult type of hand disability to treat is when multiple injuries are sustained, due to some crushing force which, apart from damaging the tendons and fracturing the bones, produces widespread scarring in the hand

In the type of crush injury to be dealt with in this section, conservative treatment offers the most hope of improvement

Industrial injuries of the hand often result in multiple fractures, tendon lesions and gross scarring and contracture These are the sort of injuries incurred when a hand is caught in machinery Severe damage to the hand is also done when the blood supply is seriously impaired This may result from local interference with the palmar arch in crush injuries of the hand, or from damage to the arterial supply in the forearm or at the elbow as in Volkmann's ischaemic contracture

The problem of vascular interference will be dealt with in a separate section

Each crush injury to the hand presents its own particular problems, as the amount of damage caused is so variable from case to case it is impossible to present figures for the average time under treatment and average functional results in different types of injury More than in any other hand disability the ultimate result depends not only on the damage caused and the delay before rehabilitation, but on the patient's job and his interest in getting better and persevering for many months in treatment Furthermore, it is not always the most obviously severe injuries that present the major problems Extensive skin loss, for example, when grafted speedily, can cause surprisingly little disability, whereas a comminuted fracture into the interphalangeal joint with tendon adherence and soft-tissue contracture can be a permanent and severe disability

Treatment

The principles of treatment in crush injuries are common to all types, the first aim is to restore movement to the stiff joints Movement may be lost in the interphalangeal or metacarpo-phalangeal joints through fractures involving the joint, capsular contraction or flexion deformity following tendon shortening and scarring in the palm To restore movement the contracted structures must be slowly stretched by the technique of serial plaster stretch splints This is combined with several sessions of oil massage to the scars in the palm and fingers, increasing in intensity as progress is achieved Meanwhile, the power of grip is improved by progressive occupational therapy and resistance exercises, and tendon function at each joint is re-educated

In the early stages any tendency for oedema to collect in the hand must be vigorously prevented Should this tendency be apparent then the patient must have the hand in elevation in a sling during the day, and at night he may require to have the arm suspended above the head

The surgical principles in extensive damage of the hand are first to make good skin loss by grafting, then to repair damage to the joints, and finally to replace lost tendon function Throughout these stages rehabilitation must continue to aim at providing the best possible conditions for the surgeon for each manoeuvre The co-existence of one or more nerve lesions can be a highly difficult problem as the deformities resulting from the over-action of muscles unopposed by their paralysed antagonists may make correction of a deformity due to shortening of muscles extremely difficult to correct

Lively splints are of considerable help in this type of disability provided there is a sufficient range of passive movement for them to be effective, and provided they are designed so as to correct deformity on one set of joints only, care being taken to see that they are not, in fact, producing deformity at another set of joints

When, for example, the extensor tendons have been severely damaged and the metacarpo-phalangeal joints are fixed in flexion, it is necessary to stretch the metacarpo-phalangeal joints into extension and at the same time to encourage function in the repaired or grafted extensors. The type of splint which pulls the metacarpo-phalangeal joints out by elastic traction through slings on the proximal or middle phalanges and taking origin from the dorsum of the forearm tend to be ineffective and to produce hyperextension deformity at the proximal interphalangeal joints. It is preferable to supply a stretch splint on the forearm and palmar surface of the hand which pushes the metacarpo-phalangeal joints into extension rather than pulling them out. This obeys the principle of designing a splint to correct deformity at one set of joints only.

Case histories

Some examples of severe multiple and crush injuries and their treatment will now be given.

Case 1. This patient caught his right hand in an airscrew, sustaining multiple lacerations of the palm, fracture of the radial styloid, compound fracture of the base of the index metacarpal with severance of the extensor tendon, fracture of the base of the proximal phalanges of the middle finger and fracture of the base of the fourth metacarpal.

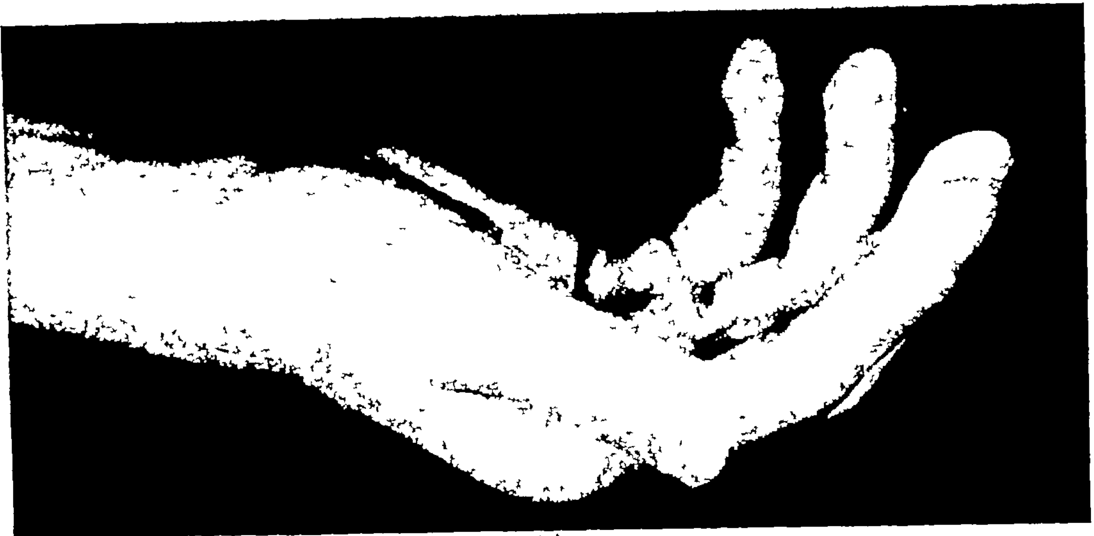
Two months' immobilization was needed before the fractures united and on removal of the plaster the hand was seen to be wasted, all the fingers were frozen with no movement at the metacarpo-phalangeal or interphalangeal joints, there was extensive tough scarring throughout the palm, no dorsiflexion in the wrist and 10 degrees palmar flexion only. The hand was cold and no grip could be recorded on the dynamometer (Fig. 59 *a* and *b*).

The patient was under intensive rehabilitation for 5 months, a progress chart recording movements is shown in Table II.

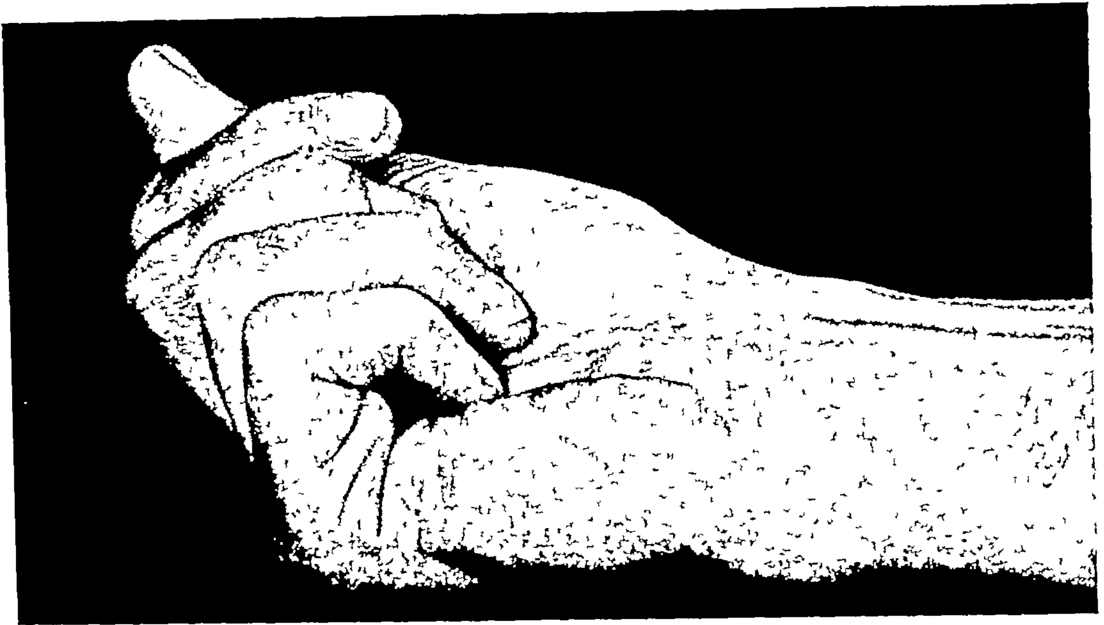
TABLE II

PROGRESS CHART (EXPRESSED IN DEGREES OF MOVEMENT) OF CASE 1

Finger	*2 months after injury (start of rehabilitation)*	*10 days later*	*38 days later*	*51 days later*	*100 days later*	*1 year later*	*2 years after injury*
Index Terminal interphalangeal	Flicker	1	10	15	40	35	50
Proximal interphalangeal	Flicker	5	30	35	65	65	70
Middle Terminal interphalangeal	Flicker	Flicker	5	7	40	90	90
Proximal interphalangeal	Flicker	5	10	10	35	75	90
Ring Terminal interphalangeal	10	10	30	45	70	90	90
Proximal interphalangeal	35	35	45	45	60	90	90



(*a*)



(*b*)

FIG 59 —*Multiple fracture of the right hand* (*Case 1, page* 150) *Maximum flexion possible* (a) *8 weeks after injury at commencement of rehabilitation and* (b) *20 weeks later*

Treatment comprised 4 sessions a day of oil massage, serial plaster stretch splints, remedial games and exercises, re-education of individual tendon function, and progressively hard occupational therapy, starting with basketry and ending with heavy carpentry Fig 59 *b* shows the final result The patient was able to return to full work as an aero-engine fitter, and on review 2 years after injury the joint movements were index finger, terminal interphalangeal joint 50 degrees (180–130 degrees), proximal interphalangeal joint 70 degrees (165–95 degrees), middle finger terminal interphalangeal joint, full, proximal interphalangeal joint 75 degrees (165–90 degrees) The grip was 9 lb as compared with 13 lb on the normal side The only disability was in the execution of very fine movements in awkward positions, but this was steadily improving


(b)

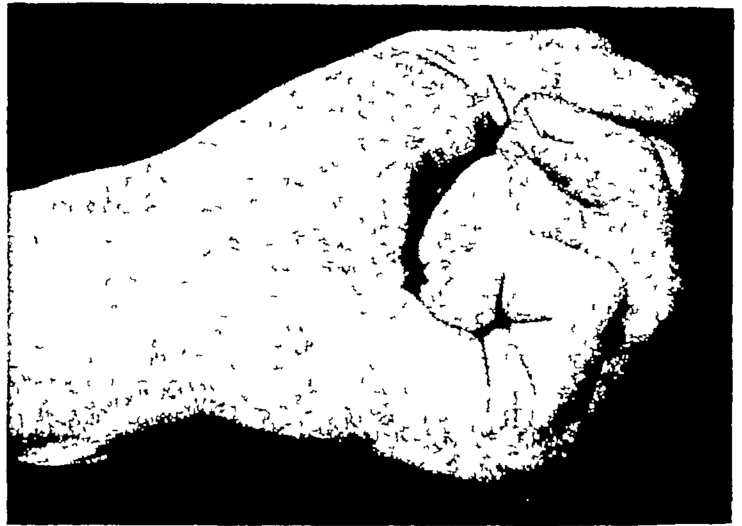
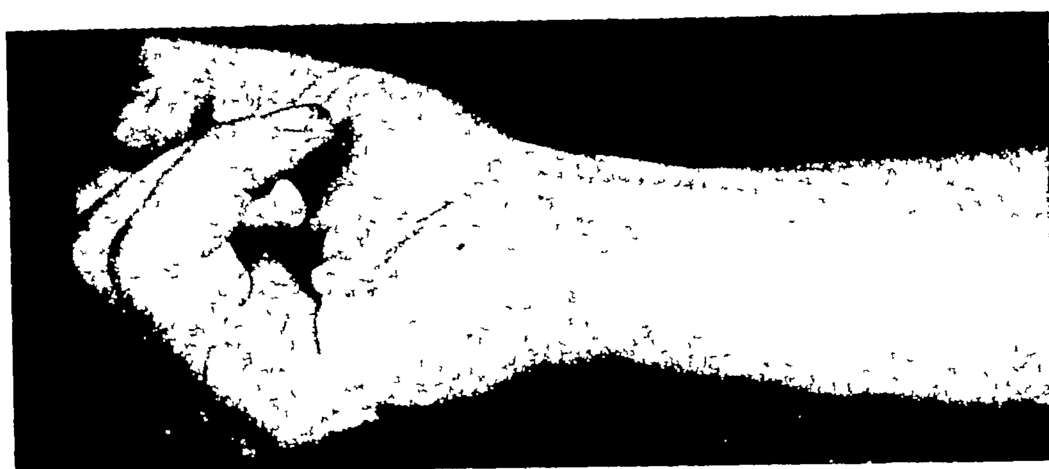

(a)

FIG 60 —*Case 2, below* (a) *Radiograph of fracture-dislocation of proximal interphalangeal joint of the left ring finger and surgical removal of comminuted head of metacarpal* (b) *Result of treatment*

Case 2 This patient sustained a crush injury to the left hand and an infected palmar wound when the tank of an aircraft fell on his hand He sustained a comminuted fracture of the head of the ring finger metacarpal, a fracture of the base of the proximal phalanx of the ring finger, partial severance of the extensor tendon of the ring finger, complete severance of the flexor tendon, and gross scarring throughout the palm of the hand (Fig 60 *a* and *b*) The head of the fourth metacarpal was removed at the time of injury Three months later a palmaris longus graft was performed on the ring finger After a further 3 weeks intensive rehabilitation was commenced

Movements at this stage were metacarpo-phalangeal joint 5 degrees (95–90 degrees), proximal interphalangeal joint 5 degrees (135–130 degrees), terminal interphalangeal joint 2 degrees (180–178 degrees) There were dense adherent scars throughout the palm, the extensor tendons in the ring finger were not working After 2 months of treatment, combining the routine treatment for flexor tendon grafts with serial stretches which began 6 weeks after grafting, there was 30 degrees movement at the terminal interphalangeal joint and 20 degrees at the proximal interphalangeal joint Power of grip was 50 per cent that of the normal side At this stage the extensor tendon was freed at operation from the metacarpal, and when tendon rehabilitation recommenced 6 weeks later movements were 30 degrees at the terminal interphalangeal joint and 40 degrees proximal interphalangeal joint, active extension was present at both joints, the grip was two-thirds that of the normal side The patient was discharged to work as an engine fitter Throughout the latter period of treatment intensive oil massage, at first 4 times a day, and later twice a day, was given

When seen 18 months later there was 20 degrees movement at the terminal interphalangeal joint and 40 degrees at the proximal interphalangeal joint, the grip was 10 lb, compared with 13 lb in the normal hand The finger could be brought to within 2 inches of the palm and function during work was good



(*a*)



(*b*)

FIG 61 —*Case 3, below End-result in comminuted compound fractures of the proximal phalanges of the middle, ring and little fingers The little finger was amputated* (a) *Maximum flexion* (b) *Maximum extension*

The problems in this patient were those of a normal flexor tendon graft, but complicated by the weakness of the extensor tendon due to its partial severance and adherence to the metacarpal together with the stiffness of the joints, due both to immobilization required for the associated fractures and the gross scarring due to the crush injury

In Cases 1 and 2 full-time intensive treatment for several months was necessary It is impossible to obtain good function in this type of injury, where gross soft-tissue damage co-exists with fractures and tendon lesions, without such intensive treatment It is our experience that encouraging such patients to obtain recovery of function by going back to work early is fruitless, for if a patient cannot carry out his job with the damaged hand, he will either seek alternative employment or use the normal hand instead Only when sufficient range of movement has been restored, and sufficient power of grip for the patient to be confident of the use of the hand, should such patients be allowed to return to work, particularly in a skilled worker, it is economically more sound to stay on full treatment for many months with the prospect of returning eventually to his normal work

Case 3 This patient sustained comminuted compound fractures of the proximal phalanges of the middle, ring and little fingers of the hand when crushed between a jack and the aircraft on which he was working The little finger had to be amputated through the base of the proximal phalanx on the day of injury Intensive rehabilitation

was started 7 weeks after injury when the patient presented with the index proximal interphalangeal joint held in 30 degrees flexion (at 150 degrees), the proximal interphalangeal joint of the middle finger in 45 degrees flexion (at 135 degrees), and the ring finger in 70 degrees flexion at the proximal interphalangeal joint (at 110 degrees)

The problem here was to restore movement to the proximal interphalangeal joints and to encourage development of power of grip in the hand which was seriously affected by the stiffness of the fingers and the amputation of the little finger Serial stretch splints were used immediately together with intensive occupational therapy and exercises After 5 weeks movements at the proximal interphalangeal joints were index finger, 170–70 degrees, middle finger, 145–70 degrees, ring finger, 130–90 degrees The patient was able to return to work as an air-frame mechanic, with excellent hand function (Fig 61 *a* and *b*)

TABLE III

PROGRESS CHART (EXPRESSED IN DEGREES OF MOVEMENT) OF CASE 4

Finger	*52 days after fracture At start of rehabilitation*	*81 days (29 days later)*	*101 days (20 days later)*	*206 days (105 days later)*
Index Terminal interphalangeal	180–90 (90)	Full	Full	Full
Proximal interphalangeal	135–90 (45)	170–90 (80)	Full	Full
Metacarpo-phalangeal	Full	Full	Full	Full
Middle Terminal interphalangeal	135–90 (45)	170–90 (80)	Full	Full
Proximal interphalangeal	110–90 (20)	130–90 (40)	130–90 (40)	135–90 (45)
Metacarpo-phalangeal	180–110 (70)	180–100 (80)	180–100 (80)	Full
Ring Terminal interphalangeal	170–90 (80)	170–90 (80)	170–90 (80)	Full
Proximal interphalangeal	90 (Nil)	90–85 (5)	90–80 (10)	Full
Metacarpo-phalangeal	180–150 (30)	180–110 (70)	180–110 (70)	Full
Little Terminal interphalangeal	170–90 (80)	Full	Full	Full
Proximal interphalangeal	135–90 (45)	130–90 (40)	150–90 (60)	150–90 (60)
Metacarpo-phalangeal	180–135 (45)	180–90 (90)	Full	Full

Case 4 This patient caught his right hand in an ambulance door, sustaining compound fractures to the proximal phalanges of the middle, ring and little fingers The hand was in plaster for 4 weeks and on removal of the plaster there was gross limitation of movements, particularly of the proximal interphalangeal joints Table III and

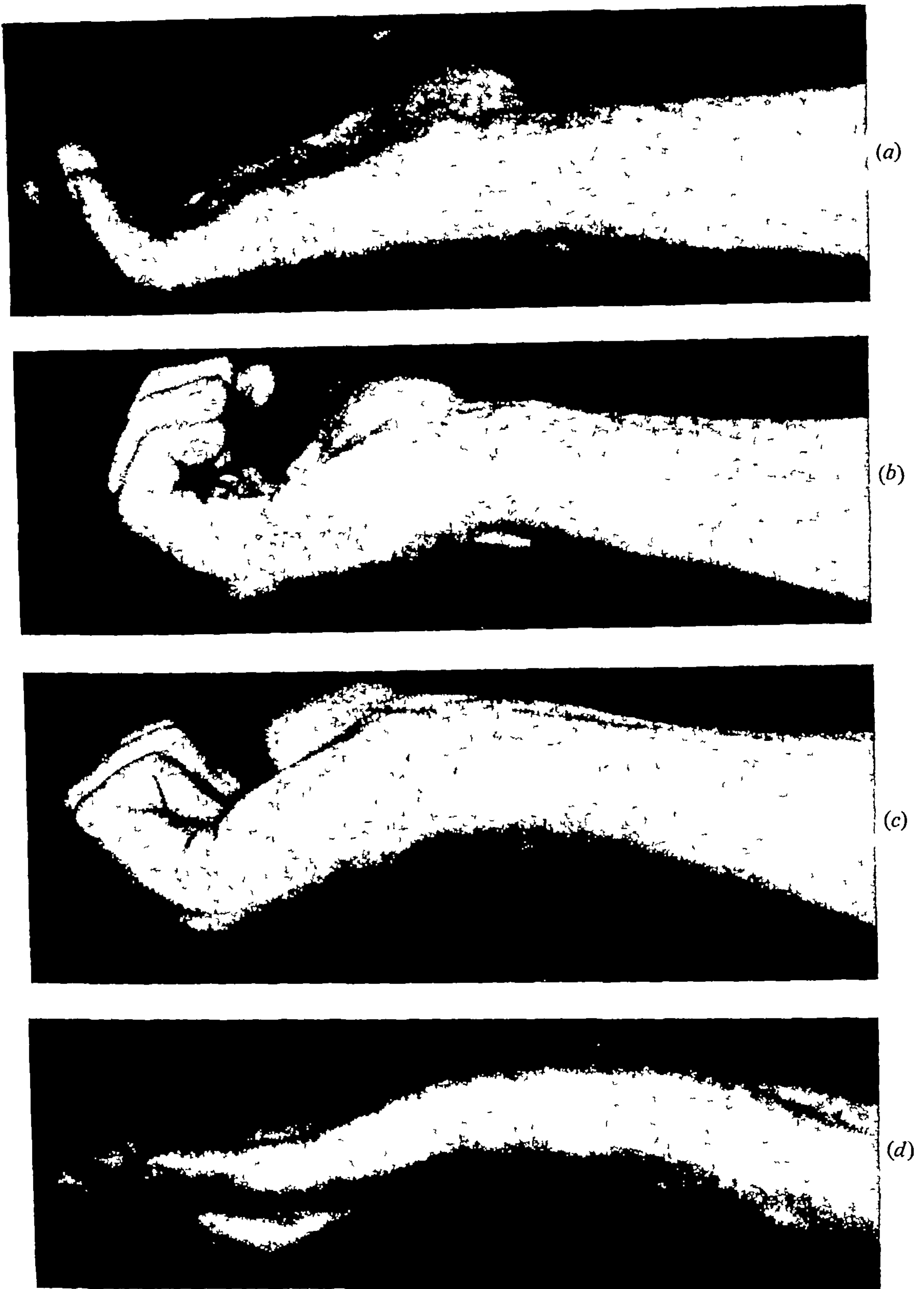


FIG 62 —*Case 4, page* 154 *Fractures of proximal phalanges of middle, ring and little fingers 4 weeks after injury, at start of rehabilitation* (a) *Maximum extension,* (b) *maximum flexion—result after 8 weeks of rehabilitation,* (c) *Maximum flexion,* (d) *maximum extension*

Fig 62 *a–d* show the progress of this case The patient was discharged after 8 weeks' treatment with good function, and when seen 3 months later movement had improved further Since discharge he had been doing the normal duties of his trade as a nursing attendant, but was wearing a night splint As function on review was so satisfactory and movements, considering the severity of injury, were so good, the splint was discarded In this patient serial splints were used from the start of treatment together with wax baths, oil massage, exercises and games

As almost all hand function involves flexion of the fingers, the type of disability described in Cases 1 and 2 will not correct itself by normal use, consequently, it is essential that such patients should have intensive treatment with stress on corrective stretch splinting if they are to obtain the best possible result

The importance of preventing oedema following hand injuries has already been stressed, particularly crush injuries where any increase in oedema leading to further fibrosis will worsen an already severe disability

Fractures in the upper limb can lead to oedema of the hand through disuse It is important that the hand should be used as much as possible, or if this is not feasible, it should be in elevation

It is tragic to see a perfect result in a shoulder following a humeral fracture, but a stiff contracted hand due to inattention to dependent oedema

There is a particular type of fibrosis following oedema in the hand, which follows injury causing haemorrhage on the dorsum of the hand This is known as traumatic peritendinous fibrosis of the dorsum of the hand This development can be minimized by early mobilization after crush injuries in this region When present intensive oil massage and stretches usually result in good function Finally, there is the shoulder-hand syndrome where stiffness of the shoulder is associated with oedema of the hand The treatment of the oedema is the same as in other conditions where oedema is present, though the response is unfortunately very slow

VASCULAR IMPAIRMENT

General

Impairment of the blood supply to the hand, when caused locally, presents the same problems as discussed under crush injuries, for the disability is due to the scarring and consequent interference with tendon function Particular care must, of course, be observed to ensure that such patients do not sustain burns, chilblains or the like Repeated warning should be given about the precautions to be observed in cold weather and in protecting their hands from possible risk of burns

Sudeck's atrophy

Sudeck's atrophy is a specific case of vascular disorder in the hand It usually follows crush injuries without fractures

This curious condition is characterized by a painful, weak, oedematous, cyanotic hand It may follow any type of hand injury but usually occurs in a certain type of person predisposed to vasomotor instability Thus, the type of person liable to chilblains, Raynaud's phenomenon, acrocyanosis, and excess sweating is much more likely to develop Sudeck's atrophy than the normal person The severity of injury bears little or no relation to the incidence of the condition—the phenomenon is seen after crush injuries and severe fractures, but also after very mild blows In our series, the patients who developed Sudeck's atrophy after minor trauma

outnumbered those in whom it followed severe injury. In 1 patient it followed an infected nail which rapidly resolved, but the Sudeck's atrophy lasted for 4 months. In almost all our cases, the personality of the sufferer was typical—introspective, worrying, apprehensive, and showing some other sign or symptom of vasomotor instability.

The skin is smooth, shiny, cyanotic—being reddish, bluish or purple. There is always oedema which does not pit, and the whole hand feels not unlike the manus succulens of syringomyelia. Radiographs show the characteristic osteoporosis of the carpus and metacarpals, which persists long after clinical recovery has occurred.

It is thought that Sudeck's atrophy can be prevented or minimized in some cases by always immobilizing the hand in cases of minor injury. It is certainly a wise precaution to do so in patients whose temperament or past history suggest vasomotor instability.

Treatment, once the original cause has been dealt with, is hard work for the hand. This is combined with wax baths in elevation in which the patient is encouraged to work the fingers (Plewes, 1953). The sooner the patient develops power in the hand and wrist muscles the quicker will the pain disappear and the vicious circle be broken.

In the early stages, partial or complete immobilization is advisable if pain is preventing hard work in the physiotherapy or occupational therapy departments.

If trigger points are found which on pressure produce pain they may be injected with local anaesthetic.

In resistant cases, the reflex arc must be broken by injecting the sympathetic plexus round the blood vessels. Bunnell (1956) advises repetition 2–3 times if the first injection is promising. If this fails ganglion injection, sympathectomy, or even cordotomy may eventually be necessary.

However, the great majority of patients recover with conservative treatment. These patients require extremely careful handling, and should be given enough work to encourage redevelopment of muscle power, and not too much to worsen the pain. Their mental attitude must be understood and a sympathetic interest, which must not encourage introspection, constantly shown. Such patients do particularly well on full-time treatment in a specialized centre.

Volkmann's ischaemic contracture

The two commonest causes of Volkmann's ischaemic contracture are tight plasters compressing the brachial vessels, or damage to the brachial vessels in dislocation or fractures of the elbow. The deformity is one in which the metacarpo-phalangeal joints are hyperextended and the interphalangeal joints flexed due to necrosis of the flexors of the wrist and the long flexors of the fingers. The extensors usually escape, and thus this overaction causes the hyperextension of the metacarpo-phalangeal joints.

The best treatment for this condition is, of course, prevention. When established, conservative measures should be tried first, but in most cases surgery is necessary. This may involve a muscle slide operation with reconstructive procedures.

Conservative measures consist basically of serial stretch splints. The principles differ in no way from those already described for overcoming soft-tissue contractures. The splintage, however, needs to be continued for many months, and the

greatest care and constant supervision are essential to guard against breakdown of the skin, and even gangrene

The patient must persevere with all the routine exercises, physiotherapy and occupational therapy If the patient is going to derive benefit from conservative treatment, some improvement will be noted within the first 3–4 weeks Surgery offers the best prospects when combined with conservative measures A surprising degree of contracture can be overcome by serial splintage, and it is well worthwhile applying this before embarking on excision of tissue and reconstruction procedures

It is important that surgery should not be undertaken until conservative measures have produced the maximum improvement It is obvious that in the case of an associated median nerve palsy, grafts to the thumb should not be undertaken until maximum correction of the adduction contracture has been obtained The following case history illustrates these points

Case 1 This patient, aged 40 years, sustained compound comminuted fractures of the medial epicondyle of the humerus, dislocation of the head of the radius, a fractured shaft of the ulna, gross muscle damage and total skin loss over the right elbow and upper arm when his right arm was trapped beneath an overturned lorry

Wound toilet was effected and the fractures reduced and set in plaster

Two further excisions of devitalized tissues were undertaken 3 days and 11 days later The median nerve was found to have partially sloughed away, and evidence of ischaemic contracture of the flexors of the wrist and fingers was clearly seen The whole area was skin grafted 9 weeks after injury

Fourteen weeks after injury the patient was transferred to the rehabilitation centre when his condition was as follows

There was an extremely tough scarred skin all around the elbow and the upper arm Elbow movements were 80–105 degrees, no rotation was present The wrist was held in 25 degrees palmar flexion, 10 degrees of palmar flexion could be obtained passively although not actively No passive dorsiflexion was possible All the muscles supplied by the median nerve in the hand were working weakly, but there was no sensation present The passive movements of the fingers were as tabulated below

TABLE IV

FINGER MOVEMENTS (DEGREES) OF CASE 1

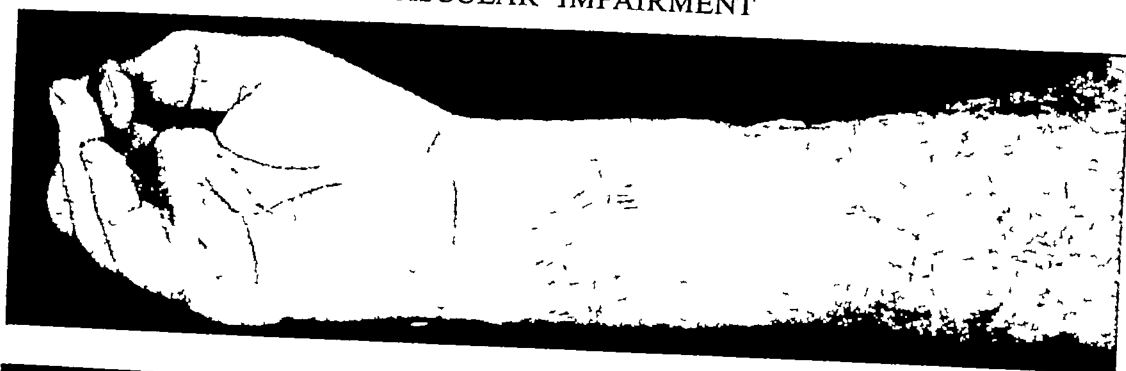
Finger	*Metacarpo-phalangeal*	*Proximal interphalangeal*	*Distal interphalangeal*
Index	155–130	108 fixed	145 fixed
Middle	155–130	117–105	180 fixed
Ring	145–128	160–145	172–168
Little	160–150	160–142	172–162

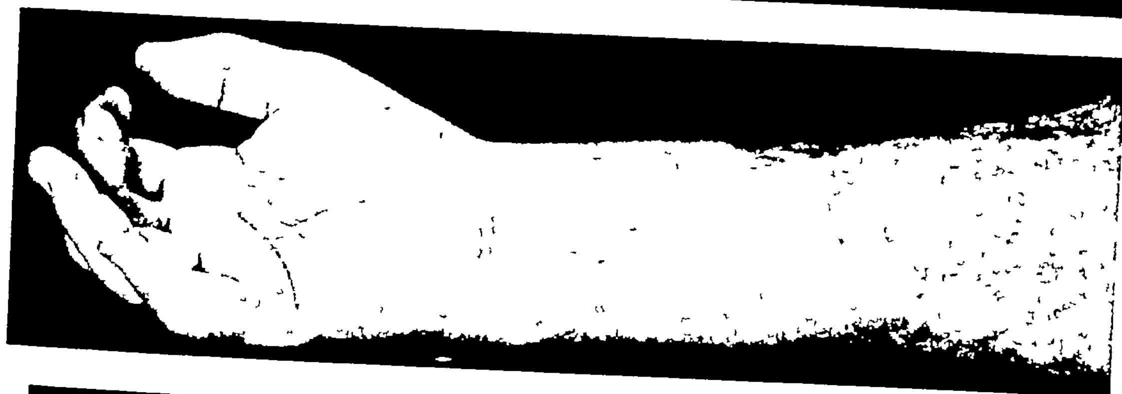
Thumb 150–149 in interphalangeal joint

On maximum voluntary wrist and finger flexion measurements from the fingertips to the wrist crease were index 4 25 inches, middle 4 5 inches, ring 5 inches, little 4 5 inches

The thumb web measured from the medial border of the thumb nail to the lateral border of the crease proximal to the proximal interphalangeal joint of the index finger was 1 inch (Fig 63 *a–d*)

This was an extremely severe injury, the hand disability being due to a severe contracture of the flexors of the wrist and fingers with muscle necrosis and a partial median nerve lesion







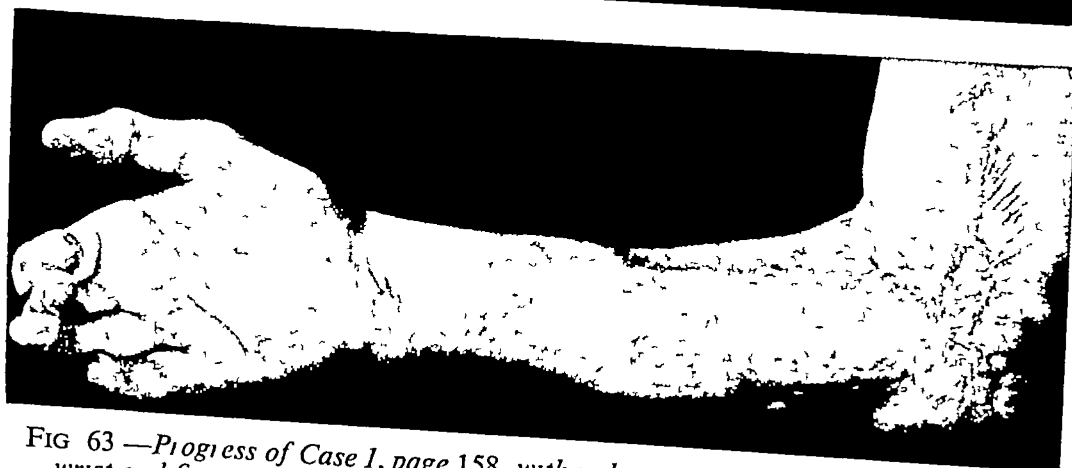


FIG 63 —*Progress of Case 1, page 158, with ischaemic necrosis of the forearm, the wrist and finger flexors* (a) *Maximum flexion and* (b) *maximum extension after 14 weeks* (c) *Maximum flexion and* (d) *maximum extension after 5 months of intensive rehabilitation*

Fortunately, the elbow limitation was little handicap as the joint was virtually fixed in the position of function

Intensive treatment continued for 5 months comprising oil massage 6 times a day, serial plaster stretches, normal stretches in warm saline solution, active exercises, all varieties of craft work starting with basketry and progressing to heavy carpentry, games in the gymnasium, and efforts to restore morale with outings and recreational activities The patient was given codeine before each session of stretching

It was never expected that a spectacular result would be achieved, but the limited objectives aimed for were the hope that the patient would feel that the hand was a part of him again, and that he would regain sufficient active flexion to grip, grasp and lift objects, and be able to manipulate coarse tools, and perhaps write

At the end of 5 months intensive treatment, measurements recorded were as follows

TABLE V

FINGER MOVEMENTS (DEGREES) OF CASE 1

Finger	*Metacarpo-phalangeal*	*Proximal interphalangeal*	*Terminal interphalangeal*
Index	170–110	128–108	145 fixed
Middle	170–110	120–95	180 fixed
Ring	165–120	160–130	175–140
Little	180–145	165–115	175–130

There was 30 degrees palmar flexion and a few degrees dorsiflexion (Fig 63*d*) Elbow movements were still 25 degrees and there was no rotation

TABLE VI

PROGRESS IN MOVEMENTS OF THE FINGER JOINTS (BY DEGREES) IN CASE 1

Finger	*Metacarpo-phalangeal*	*Proximal interphalangeal*	*Terminal interphalangeal*
Index	+ 35	+ 20	Nil
Middle	+ 35	+ 13	Nil
Ring	+ 28	+ 15	+ 31
Little	+ 25	+ 32	+ 35

This degree of improvement made all the difference to function, for on discharge the patient could grasp most tools, write, dress easily, grip large objects, carry heavy weights, and he felt the hand once again belonged to him He was convinced that all the hard work and pain was worthwhile, and his morale could not be higher

There is another type of ischaemic contracture which occurs in the hand (Bunnell, 1953) cases have occurred due to obstruction of the circulation in the hand itself by a too tightly applied plaster This causes degeneration of the intrinsic muscles The deformity is one in which the metacarpo-phalangeal joints are flexed and the interphalangeal joints extended The thumb is held in the palm due to adductor contracture

This deformity is the reverse of intrinsic paralysis where the metacarpo-phalangeal joints are hyperextended and the interphalangeal joints flexed The intrinsic muscles are fibrotic, shortened, and thus produce what Bunnell has termed the " intrinsic plus position " as opposed to the " intrinsic minus position " in intrinsic paralysis A good sign of intrinsic contracture is to tap on the finger-nail. The

interphalangeal joints cannot flex owing to the strong resistance afforded by the contracted muscles

There are a number of reconstructive procedures that have proved of value in this condition Bunnell (1953) originally described an operation in which he divided the intrinsic tendons at their attachment to the extensor expansion Littler (cited by Bunnell, 1956) modified this procedure by removing the oblique fibres but preserving the transverse fibres Thus, the intrinsic action was preserved at the metacarpo-phalangeal joint and abolished at the interphalangeal joints Rehabilitation is directed towards encouraging the patient by exercises and occupational therapy Adductor contracture, if incurable, will certainly require excision of all the fibrotic muscles followed by an opposition graft

HEMIPLEGIA

The remarks under this section apply in general to all spastic conditions of the hand

General

Anything more than a transient hemiplegia results in permanent paralysis of the intrinsic muscles of the hand Lumbrical and interosseus action hardly ever returns

There may be some coarse movement in the thumb, even some opposition, but controlled fine movements are not possible

All that can be expected of a hemiplegic hand is coarse grip and support Even grip may be adversely affected by the spasm and tremor if present Prognosis for function depends, of course, on the extent of the damage and the age of the patient—young patients do better than old ones It is important, therefore, not to lead the patient to hope for a complete recovery

The patient should be encouraged from the outset to use the sound hand for everything, in particular to learn to cope with his toilet activities one-handed, and to write with his unaffected hand

So often the hemiplegic patient is " waiting for his hand to recover " and will not use his good hand The sense of frustration that occurs when recovery does not result may utterly warp the patient's whole outlook and future life The therapist must work to limited objectives

The attitude to encourage in the patient is thankfulness for any recovery that does occur but no expectations

Physiotherapy

Formal

The first aim is to remove the tightness from the shoulder before the hand can be used to any extent

Passive movements to restore full free range are given first to the shoulder then to the elbow, the wrist and the fingers The stiff shoulder is the big enemy of the hemiplegic, it must not, therefore, be allowed to get stiff

As the flexor overaction is the main cause of extensor weakness, the flexors must be relaxed The arm is put into the optimum position for relaxation—most often found to be in prone lying The extensor thrust is then used for re-educating

the extensors in which the whole arm, the shoulder, the elbow, the wrist and fingers, are actually extended in a thrust against the physiotherapist's resistance

If spasm is troublesome, the spastic muscle or muscle group is deliberately fatigued by exercising, and relaxation follows Immediately afterwards the weak antagonist is re-educated in the usual manner

In the hand such fine movements as are available are re-educated, without expecting intrinsic muscle action to return

Thumb movements often cannot be initiated by the patient, but appear in gross pattern movements The patient, by hard concentration, can sometimes extract this movement from the gross action and may eventually be able to initiate it himself Another useful method is to coax the muscles to act by training them as synergists as, for example, in the flexors of the fingers and the extensors of the wrist working together in grip

Any tendency to oedema must be countered by elevating the arm in a sling, sleeping with the arm elevated at night, and exercising actively to encourage drainage

Games

All varieties of card games are extremely useful in the re-education of the hand in hemiplegia Shuffling, dealing, making card houses, all exercise moderately fine hand movements and promote co-ordination

Any form of game that promotes co-ordination based on Fraenkel's principles is worth encouraging—these include peggoty and draughts

Daily activities

All the daily activities of ordinary living—tying shoes and ties, getting dressed, buttering bread, cutting up meat—must be taught to the patient so that he can do as much as possible one-handed and unaided

WRITER'S CRAMP

The treatment of writer's cramp is the province of the psychiatrist

The physiotherapist can help by padding the pen or pencil, and giving heat and relaxation exercises in an attempt to reduce the spasm Any such measures are merely symptomatic

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CHAPTER 6

THE RHEUMATOID HAND AND ITS MANAGEMENT

BY D A BREWERTON

INTRODUCTION

THE problems of management of the rheumatoid hand and the injured hand differ in many respects The problem of the rheumatoid hand is nearly always complicated First, even when the symptoms are mild, many joints, muscles and tendons may be involved in the rheumatoid process Secondly, it is unusual for the hands to be the patient's only problem, and the management of the hands may be influenced by the condition of other joints such as the wrists, the elbows, the shoulders or even the feet Thirdly, the process within the hands is continuing, variable and unpredictable With the injured hand it may be possible to assess the extent of the damage and plan a period of intensive rehabilitation that will restore maximum function By contrast, the approach to the rheumatoid hand is more one of supervision for months or years advising the patient, relieving pain, attempting to minimize deformity, and tackling new difficulties as they arise No two patients present the same problems, and no individual patient presents the same problem for any great length of time

STIFF JOINTS

There are 2 main processes that lead to reduced range of joint movement (1) active inflammation causing pain and swelling, and (2) permanent deformity due to a variety of changes in the joint and surrounding structures These processes are usually found together in individual patients, but for prognosis and treatment it is useful to consider them separately

ACTIVE INFLAMMATION OF JOINTS

The extent and severity of joint inflammation at the onset of rheumatoid disease are extremely variable Often the inflammation is mild and causes only minimal symptoms, so that the patient may not even think it is worth consulting a doctor about them More commonly it is gradual in onset but sufficiently troublesome to interfere with work or household duties Only a small percentage of patients have an explosive onset with widespread polyarthritis making bed-rest essential

The proximal interphalangeal joints and the metacarpo-phalangeal joints are most often affected, and their involvement causes general restriction of all movements Loss of function is partly due to the inability to flex the fingers, but most important is the pain that occurs when any strain is applied to the joints

Clinically, the stage of inflammation continues for weeks, months or years, and then usually it subsides It is unusual for active and troublesome inflammation

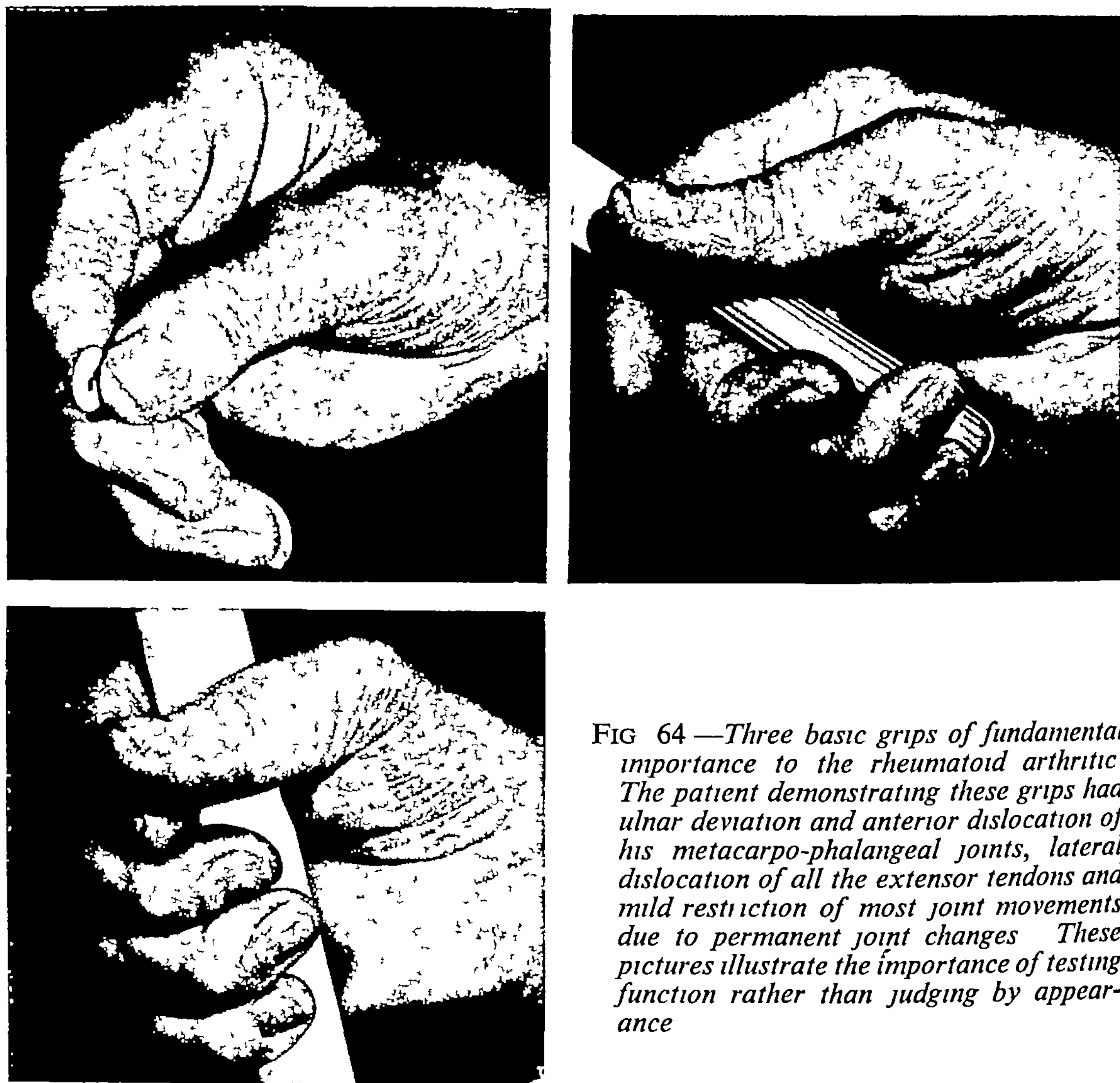


FIG 64 —*Three basic grips of fundamental importance to the rheumatoid arthritic The patient demonstrating these grips had ulnar deviation and anterior dislocation of his metacarpo-phalangeal joints, lateral dislocation of all the extensor tendons and mild restriction of most joint movements due to permanent joint changes These pictures illustrate the importance of testing function rather than judging by appearance*

to continue for more than 5 years As the active inflammation subsides and the swelling diminishes, function usually improves, but the permanent deformities that have occurred become more apparent

PERMANENT STIFFNESS OF JOINTS

Permanent restriction of joint range is usually due to pathological changes in and around the joints themselves These have their origin during the stage of active inflammation, but it is usual for them to increase slowly and for the deformities to become more apparent during the years that follow

Inability to flex the fingers

Inability to flex the fingers is the most important deformity in the rheumatoid hand It is much more liable to interfere with function than an equivalent loss of extension But it is incorrect to think that the effect of joint stiffness on function can be judged by getting the patient to make a fist Such a grip is seldom used during everyday tasks, and there are 3 other basic grips that are more important (Fig. 64) For the first grip between the finger and thumb, the index

and middle fingers need to flex through only half their normal range In the second grip the ring and little fingers must flex almost fully in order to hold the handle of a knife against the palm or thenar eminence The third grip requires only half the normal range of flexion in all the fingers This means that a slight loss of flexion in the ring and little fingers interferes with the gripping of objects with a long, thin handle, whereas flexion loss must be severe to interfere with either of the other two grips

The effect of stiffness on function also varies according to the joints involved Flexion takes place at 4 sets of joints the carpo-metacarpal joints, the metacarpo-phalangeal joints, the proximal interphalangeal joints, and the distal interphalangeal joints These are not usually involved equally, and it may be that one set of joints is very limited in range while others in the same hand are normal The metacarpo-phalangeal and proximal interphalangeal joints have the most important effects on function Flexion of the metacarpo-phalangeal joints is most important, and even a few degrees loss of movement in the ring and little fingers may interfere with function Loss of flexion in the proximal interphalangeal joints causes little inconvenience when it is slight, but it is most important when the loss is more marked In the ring and little fingers the critical angle is 120 degrees, for when flexion to this point is impossible the handle of a knife cannot be gripped firmly On the other hand, inability to flex the index and middle fingers beyond 135 degrees may have little effect on function The carpo-metacarpal joints of the ring and little fingers have only a small range of movement, even in normal people, but this range is important for full flexion and opposition of these fingers These two joints may become restricted in range and are frequently ankylosed when there is ankylosis of the wrist, Fortunately, this seldom interferes with function as the ankylosis is usually in a flexed position Loss of flexion of the distal interphalangeal joints is seldom disabling

Not all this restriction of joint flexion is due to changes in and around the joints Contractures of the intrinsic muscles of the hand may lead to hyper-extension of the proximal interphalangeal joints, and this in turn may lead to severe loss of flexion The joints may even become fixed in a hyperextended position (Fig 65) Such marked loss of flexion in all the fingers is not common but it is one of the most disabling deformities in the rheumatoid hand It prevents the patient from taking a firm grip on a handrail, a crutch, or a knife, and it may make it impossible to oppose the thumb and fingers for handling small objects

Loss of passive extension of the fingers

This must be severe to cause disability, and such loss is uncommon Occasionally, a patient is unable to grip a glass tumbler because of lack of finger extension, but it is rare for this to interfere with the handling of small objects The only exceptions to this rule are the unfortunate few who are bedridden and neglected Once they give up the use of their hands throughout the day they may develop severe flexion contractures with the finger-nails digging into the palms

Loss of thumb movement

Loss of thumb movement is most important and deserves more emphasis than it has received in the past Opposition of the thumb may be restricted due to loss of internal rotation in the carpo-metacarpal and metacarpo-phalangeal



FIG 65—*Hyperextension of the proximal interphalangeal joints due to intrinsic muscle contractures Note also the flexion of the distal joints and ulnar deviation of the metacarpo-phalangeal joints*



FIG 66—*An " adduction grip " due to loss of internal rotation of the thumb*

joints This is seen in one-third of patients attending hospitals Some can grip small objects only by adducting the thumb against the index finger (Fig 66)

Loss of abduction of the thumb is uncommon but it is important when it does occur It may prevent holding a crutch or handrail between the thumb and index finger

THE TREATMENT OF STIFF JOINTS

The treatment of active inflammation in the hand is largely the treatment of the disease itself This includes general management of the patient and the use of systemic drugs A decision on the amount of active use of the hand that is advisable provides a constant dilemma, rest is the best treatment of an

inflamed joint, while movement may help to prevent permanent stiffness No rules can be established to solve this problem and in practice social necessity usually forces the patient to do more than is advisable Where possible this uneven struggle between the patient and painful joints should be avoided

A young housewife had active inflammation confined to the joints of the hands which were uniformly swollen and painful It was a problem to know how to help her until it was discovered that she had 6 children under the age of 8 years, her wringer was old and broken, and she was doing all her washing and wringing by hand A modern wringer bought with special hospital funds produced dramatic relief of pain and stiffness

Splints

Splints can be used to rest the joints but they make the hand useless while being worn There is no practical form of lively splinting that will support the joints during functional activities This means that splints are only worn in bed to relieve pain during the night, or occasionally for rest throughout the day when the patient is confined to bed with joint inflammation of exceptional severity

Rest splints should be as light as possible Plaster of Paris is easy to handle and is still the material used most frequently, but in some hospitals it has been replaced by polythene as this is lighter and easier to keep clean Brennan (1954) described a method using polythene and polyurethane The two plastics are heated in an oven to 120°C As polyurethane is a poor conductor of heat the materials can be bandaged on to the limb with the polyurethane in contact with the skin They then conform to the shape of the hand and on cooling harden in that position

Whatever the material used, the splint must extend from the middle of the forearm to the finger-tips (Fig 67*a*) The fingers should be partially flexed and the thumb internally rotated almost to a position of opposition It is wrong to use a flat splint with the fingers extended and the thumb externally rotated This is uncomfortable and encourages loss of finger flexion and of internal rotation of the thumb If a rest splint is to be worn throughout the day, it must be removed at least twice a day for exercises

It must be remembered that loss of function in the hand is often aggravated by pain in the wrist, and this may be relieved by a moulded leather or polythene wrist support This measure probably does more than any other to assist the function of the rheumatoid hand (Fig 67*b*)

Heat

Heat is often used to relieve pain and to overcome joint stiffness It cannot be expected that the effects of heat are either lasting or curative, but they do help patients to overcome temporary stiffness, and heat is of undoubted value in preparation for passive or active finger exercises

The choice between paraffin wax baths, hot water and radiant heat is based mainly on convenience and the patient's preference In practice most patients prefer paraffin wax

Exercises to prevent or overcome joint stiffness

These have a value that is difficult to define There are times when voluntary movements are prevented by severe pain or by tendon lesions, and in these circumstances there are strong indications for regular assisted or gentle passive



FIG 67 —*Splints used in the rheumatoid hand* (a) *A plaster of Paris rest splint* (b) *A polythene wrist support*

exercises There are equally good reasons for giving " wax and exercises " to a small group of patients with arthritis of recent onset who feel abandoned if no treatment is given But these indications do not apply to the majority of patients At least 50 per cent of them are busy in their jobs or in the home, and have few symptoms, and most of the others are using their hands throughout the day performing the normal tasks of living This leaves only a few for whom it is reasonable to attend hospital physiotherapy departments as an outpatient for formal exercises These are most likely to be helpful when the joints are inflamed, as patients left to their own devices tend to avoid the movements that they find painful or difficult It is also reasonable to try the effects of treatment in doubtful cases, and continue to treat the patients who genuinely feel that treatment improves their hands and makes them more supple

The choice between active, assisted and passive movements is best left to the person treating the patient, for all three types of exercise may be useful for the same hand The guiding principle is that no joint should be forced or made worse Active movements are sometimes adequate when the hands have been warmed in paraffin wax, sometimes a little gentle assistance is required, in some cases movement is better when it is resisted, while in others the best results are obtained when the hand is completely relaxed It is an art to move the joints through the fullest range with the minimum of strain

In giving exercises all joint movements should be obtained, but special attention should be paid to those movements where loss most often results in disability It has already been emphasized that the most important joint movements are flexion of the metacarpo-phalangeal and proximal interphalangeal joints of the fingers, and particularly those of the ring and little fingers In the thumbs the important joint movements are internal rotation, abduction and adduction

The responsibility of the physiotherapist does not end with the formal treatment These periods of exercises provide her with a chance to teach the patients about exercises to be done at home, to advise patients about the correct use of their hands for everyday activities, and to encourage them when they become dispirited

The correction of established joint stiffness

This is very difficult and should seldom be attempted The problem is not the same as it is for the injured hand Rheumatoid joints are much more likely to be damaged by strain, and this may cause pain, increased stiffness, or joint instability

Despite these dangers there are rare occasions when the fingers become so flexed that something must be done to restore function Very gradual stretching is essential, and may be applied by using serial plasters, renewed frequently so that the strain on the joints is always slight Alternatively, special splints can be made so that each finger is gradually extended by an individual spring and sling

It must be realized that a rest splint to relieve joint inflammation and a correction splint are quite different both in purpose and mode of action When making a splint it is essential to remember its purpose, for the two types of splint cannot be combined

UNSTABLE JOINTS

An increased range of joint movement is common in the rheumatoid hand The primary causes of these deformities are degenerative and destructive processes in and around the joints, but these are aggravated by functional use of the hand and by the abnormal pull of contracted muscles or dislocated tendons

Ulnar deviation and anterior subluxation of the metacarpo-phalangeal joints

These occur in approximately 25 per cent and 20 per cent of patients respectively, and they usually occur together (Fig 68) It is true that they also occur independently, but when they do the resulting deformity is usually mild The more severe and unsightly deformities start with a mild antero-medial subluxation which increases slowly until there is an antero-medial dislocation As this takes place the more medial extensor tendons dislocate to the medial side of the metacarpo-phalangeal joints These tendons then aggravate the ulnar deviation, as they no longer pull along the line of the fingers, and they become inefficient in their normal task of extending the fingers

There are several reasons why ulnar deviation develops, but the relative importance of each is still not clear The inflammatory processes in and around the metacarpo-phalangeal joints leave the ligaments and capsules loose and liable to be stretched Then many daily activities of the hand subject these joints to severe strains that could lead to subluxation in an anterior or a medial direction Finally, contractures of the intrinsic muscles and dislocated tendons are both definite primary causes of ulnar deviation in a small number of patients, and they contribute to its development in many more

The importance of ulnar deviation has been exaggerated by some authors In fact, its effect on function is usually slight and the essential grips are performed normally The ability to flex the fingers is lost no more frequently than it is in the

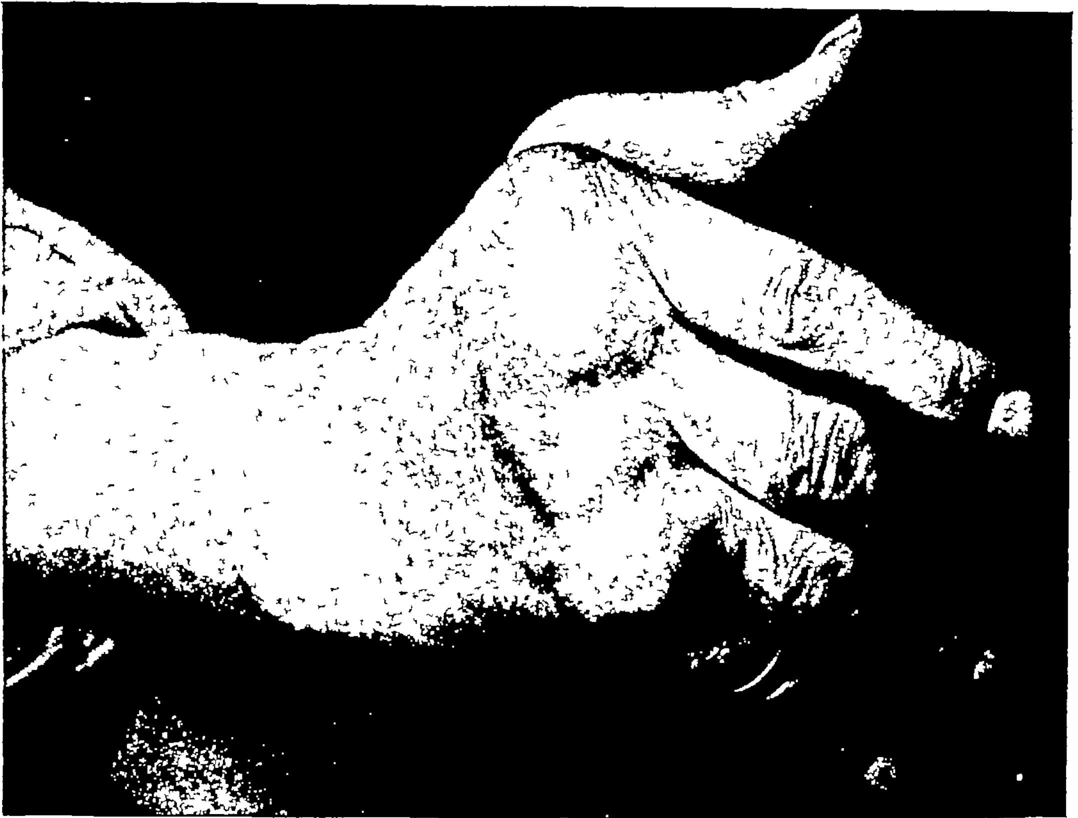


FIG 68 —*Ulnar deviation and anterior subluxation of the metacarpo-phalangeal joints All the extensor tendons have dislocated into the grooves between the metacarpal heads*

absence of ulnar deviation, and it may be increased in patients with severe antero-medial subluxation or dislocation A firm grip between the thumb and the index finger is sometimes weakened when the ulnar deviation is severe and has spread to include the index finger Mild loss of passive extension of the metacarpo-phalangeal joints is common but is not usually disabling, and patients are more likely to have difficulty with loss of active extension due to dislocation of tendons This makes it difficult to pick up large objects such as a glass tumbler Despite these minor disabilities, for the average patient the most important result of ulnar deviation is its effect on appearance

Hyperextension of the proximal interphalangeal joints

This is seen in approximately 13 per cent of patients It sometimes starts as a mild congenital hyperextension and becomes exaggerated following rheumatoid involvement of the joints, but more commonly it is due to intrinsic muscle contractures (Fig 65)

The importance of this deformity does not depend on instability but on interference with finger flexion When initiating active flexion from a hyperextended position the flexor tendons are mechanically inefficient and the movement becomes jerky and erratic As has been mentioned, the joints may eventually become fixed in their hyperextended positions, having a severe effect on hand function

Lateral instability of interphalangeal joints

This is an occasional finding, usually confined to one or two joints in which

destruction has been extensive Widespread instability of the type known as "arthritis mutilans" is rare

Lateral instability of the metacarpo-phalangeal joint of the thumb

This is common, and there may be an increase in range of movement of 45 degrees Sometimes its onset is sudden and follows minor trauma, but more often it is gradual and is due to a degenerative process in the collateral ligament

The effect is not serious when the thumb can be internally rotated to give a firm grip between the thumb and the index finger, but when internal rotation is limited and small objects must be gripped by adducting the thumb against the index finger, the lateral instability may weaken the grip so that it is impossible to use a key or turn a gas-tap (Fig 69)

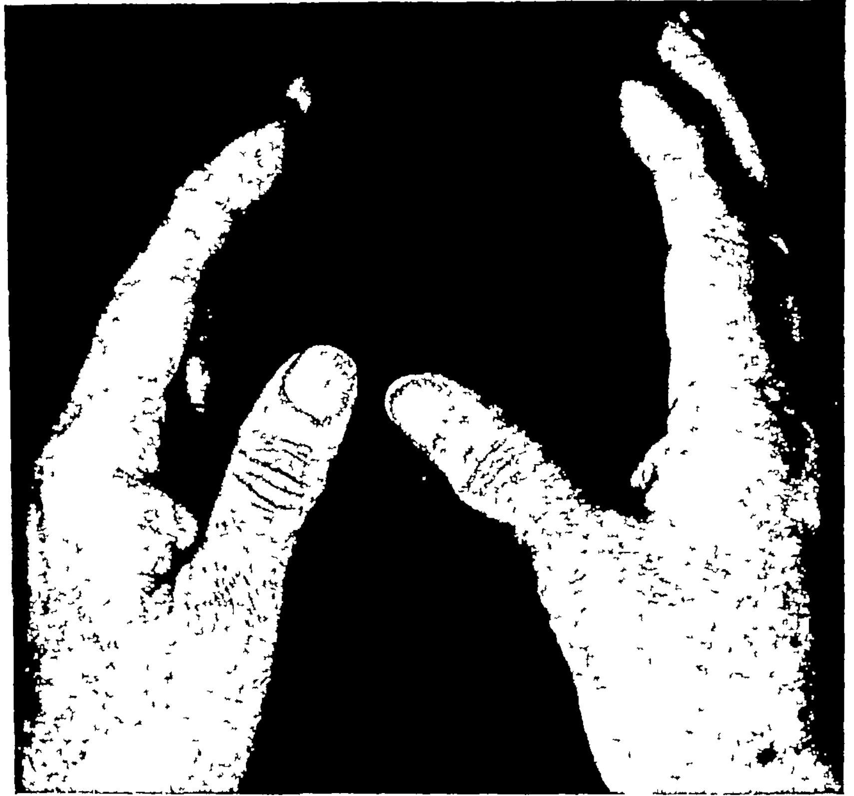


FIG 69 —*Lateral instability of the metacarpo-phalangeal joint of the thumb*

Instability of the interphalangeal joint of the thumb

Instability of the interphalangeal joint of the thumb occurs only occasionally, but when it does it may interfere with delicate grips between the thumb and finger Hyperextension or lateral instability may be so marked that these grips become quite impossible

THE TREATMENT OF UNSTABLE JOINTS

The prevention of joint instability is much more rewarding than its treatment, for once a joint becomes unstable it is virtually impossible to prevent it becoming more unstable This problem must be considered during the early stages of joint inflammation for it is then that joint instability has its origin The important principles are as follows

(1) Treatment of the inflammation to reduce the destruction of joint tissues

(2) The avoidance of strain on the joints during the period of active inflammation

(3) The prevention of contractures of the intrinsic muscles of the hand (*see* page 173)

Avoidance of strain

The avoidance of strain on the inflamed hand is an ideal that is difficult to achieve Rest in bed, preferably in hospital, is the only realistic method of resting the hands Otherwise there are always taps to turn, doors to open and saucepans to lift Unfortunately, few rheumatoid patients can rest in bed and virtually all patients are forced by circumstances to do many things that are harmful for their hands In the patient's interests arrangements should be made for relatives or a home help to assist with the housework and cooking, but this still leaves many activities that the patient must do herself Gadgets and self-help appliances may help (*see* page 179)

Splints

During the stage of active inflammation splints have the dual function of relieving the inflammation by rest and preventing strain on the joints

Later, when joint inflammation is less and joint instability is becoming established, splints are much less rational For instance, in the treatment of early ulnar deviation it is a common practice to apply night splints to minimize joint instability It is true that this may reduce inflammation, but it is not a realistic method of relieving joint strain when the patient is at home struggling to manage her housework throughout the day

At a still later stage, patients with advanced ulnar deviation and anterior dislocation of their metacarpo-phalangeal joints are often treated with night splints designed to correct these deformities This seems quite unjustified as the dislocation has already occurred, and it is impossible to believe that lasting correction will result from night splints

Surgery

To overcome instability, surgery is usually directed against ulnar deviation and the other deformities associated with it The commonest procedures are for the metacarpals to be shortened by removal of the metacarpal heads, or by removal of their bases There are no detailed accounts of the results of such operations No large group has been followed over a prolonged period When deciding on these operations it is important to remember that loss of flexion in the metacarpo-phalangeal joints is the deformity most likely to cause disability, and that many of the deformities which look severe and disabling allow excellent function

Instability of the metacarpo-phalangeal or interphalangeal joints of the thumb is often very disabling and may make it impossible to pick up and handle small objects, or to twist handles and gas-taps This instability in the thumb can be overcome by arthrodesis or ligament repair There are no published results of such operations but they undoubtedly can restore excellent function in selected patients Before operation for lateral instability of the metacarpo-phalangeal joint it is important to see that there is a reasonable range of abduction in the carpo-metacarpal joint, otherwise the operation may make it impossible to hold a crutch or handrail

Permanent splints to overcome instability are not readily accepted by rheumatoid patients and probably have little or no place in treatment Temporary splints to stabilize the thumb are useful when coming to a decision about surgery

WEAKNESS OF THE INTRINSIC MUSCLES

Weakness of the intrinsic muscles of the hand has been used in the past to explain virtually all the deformities that occur in the rheumatoid hand This view is difficult to evaluate but it seems more likely that muscle weakness contributes only slightly to deformity By contrast, it is certain that it has an important effect on function Any grip depends on the intrinsic muscles for strength, and this is doubly so when the joints are unstable

TREATMENT

When the hand is painful the most that can be expected is to avoid excessive atrophy Strong muscle contractions at this stage are inadvisable as they are likely to make the hand more painful It is better to restrict muscle exercises to gentle activity within the least painful part of the joint range

Results are much better when joint inflammation has subsided and the muscles are again able to contract strongly The performance of everyday functions and occupational therapy will do much to restore strength at this stage, but these can be aided by strong static exercises, such as gripping a firm rubber ball

SPASM OR CONTRACTURE OF THE INTRINSIC MUSCLES

Contractures of the intrinsic muscles have already been described (*see* Chapter 5) The similarity between the deformities due to intrinsic muscle contractures complicating trauma and certain deformities in the rheumatoid hand led Bunnell (1955) and others to suggest that intrinsic contractures were a common cause of deformity in rheumatoid disease In a recent survey these contractures were found in 13 per cent of a group of hospital outpatients They start early in the disease process as a variable spasm that is reversible, and progress to fibrous contracture over a period of years

It is probable that these contractures are the principal cause of hyperextension of the proximal interphalangeal joints (*see* Fig 65) They may also contribute to ulnar deviation and anterior subluxation of the metacarpo-phalangeal joint, but this is difficult to assess as, once the deformities are established, the joints are too stiff to allow examination for muscle contractures

TREATMENT

Although the exact importance of these contractures is not yet established, the evidence is sufficiently strong to warrant determined efforts to prevent them Furthermore, there may be a period of years between the onset of spasm and the deformities that may arise from it During this period prevention should be possible No form of active splinting is practical and movements that will stretch these muscles are seldom used in everyday activities Consequently, it is important to teach the patients to stretch these muscles regularly as a deliberate exercise (Fig 70) The interphalangeal joints must be flexed fully, and then the metacarpo-phalangeal joints are extended This is done actively, although a

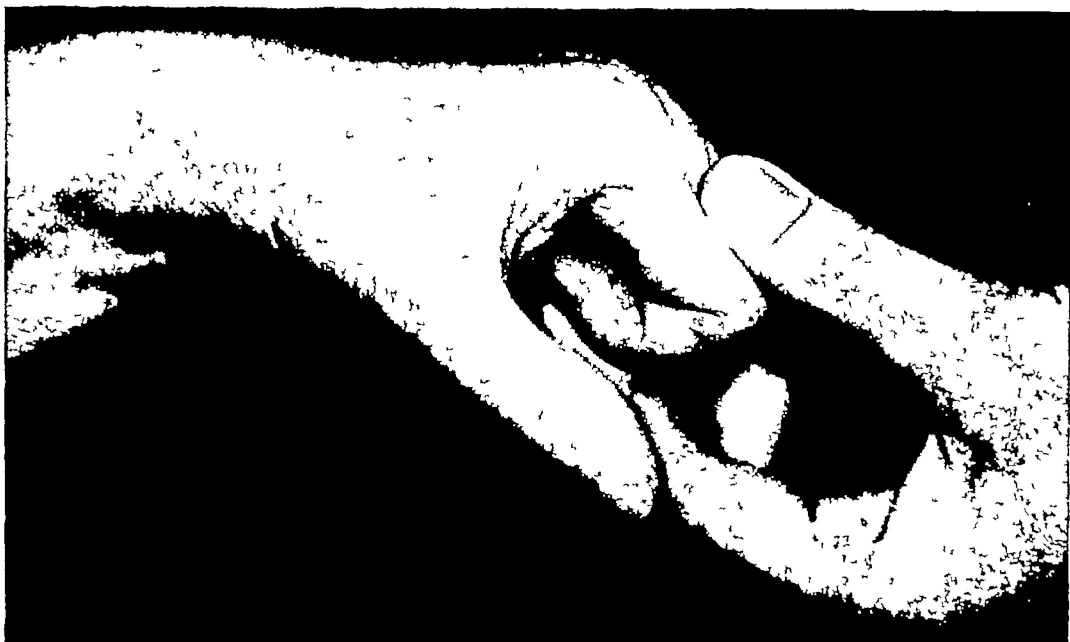


FIG 70—*Stretching the intrinsic muscles The interphalangeal joints are held flexed and the metacarpo-phalangeal joint is then extended gently If possible, this movement is done actively instead of passively*

little assistance from the opposite hand may be permitted These exercises should be repeated several times a day.

Surgery

For the established contractures surgery is now widely used, but as yet there are no detailed accounts of the results The commonest procedures are division of the lateral slips of the extensor tendons, and operations to move the origin of the intrinsic muscles to a more distal position on the metacarpals The problem is to find patients who are fully suitable for such operations, as function is usually adequate up to the time that the interphalangeal joints become stiff, and once they are stiff the results following operation are less satisfactory

TENDON LESIONS

At least two-thirds of the patients attending hospitals as outpatients have clinically demonstrable tendon lesions at some time during the course of their disease

Flexor tendon lesions

Flexor tendon lesions within the hand are very common The tendons themselves may become swollen and small nodules appear on their surfaces (Fig 71) These nodules cause difficulty as they pass beneath the transverse bands that keep the tendon in place, and as a result they cause a variety of symptoms

Trigger finger is the name given to a finger that can flex normally but tends to become stuck in the flexed position so that it must be extended passively using the other hand This symptom usually starts early in the disease and disappears within a few months, although occasionally it may persist for years Secondary joint stiffness is uncommon and always mild When the nodules are larger or become impacted there is loss of active finger flexion This means that the finger



FIG 71—*Nodule formation on a rheumatoid tendon* (By permission of Professor J H Kellgren)

can be actively flexed only through a few degrees, even when the passive range of joint movement is normal Although less common than a trigger finger, in many ways it is more important It is more likely to interfere with function, it usually does not clear spontaneously, and it often leads to secondary joint stiffness Minor flexor dysfunction due to tendon lesions is common and interferes with normal function in many minor ways, but it does not actually prevent active flexion or active extension

Spontaneous tendon rupture

This is seen in approximately 6 per cent of hospital outpatients It occurs almost exclusively in the extensor tendons, particularly extensor pollicis longus and the extensor tendons of the ring and little fingers Pain at the time of rupture is mild but the patients always remember it as a sudden episode when they lost some function which was previously normal The effect on the function of the hand is usually slight compared with the disability already present due to other deformities, but there is one rare exception to this general rule Rupture of flexor pollicis longus may lead to severe hyperextension of the interphalangeal joint and a poor grip between the finger and thumb

Partial rupture

Partial rupture of tendons, with fibrous replacement and consequent elongation of the tendon, occurs occasionally, leading to partial loss of active extension or

flexion of interphalangeal joints This seldom affects function except in partial rupture of flexor pollicis longus and " button-hole " deformity of the extensor tendons of the fingers

Tenosynovitis

Tenosynovitis at the wrist is common and may be associated with pain in the wrist It seldom affects function

TREATMENT OF TENDON LESIONS

Trigger fingers and minor flexor tendon lesions

In most patients these lesions disappear spontaneously and without doubt the main principles of treatment should be conservative, not surgical, as has been suggested by some surgeons The nature of the problem should be explained to the patient so that she knows what to expect and how to avoid making the condition worse It is surprising how often patients get into the habit of flexing their fingers incessantly throughout the day in the belief that this will prevent stiffness The other conservative measure of value is an injection of hydrocortisone (25 milligrams) into the tendon sheath No series of patients treated by this method has been published so far but its value is widely recognized Patients who have had this symptom for months may get permanent relief within a few hours after a single injection Good results are more likely when both the symptom and the disease are of recent onset Surgery is indicated in a very small number of patients who have persistent and troublesome symptoms

Loss of active finger flexion

This is more of a problem than triggering as it carries a worse prognosis and may lead to secondary loss of passive joint flexion Deliberate but gentle passive movements several times each day are indicated Hydrocortisone injections may be effective, but they are less likely to be successful than in the treatment of triggering Surgery is more strongly indicated than it is for triggering, particularly when joint inflammation is mild and tendon involvement is confined to one or two fingers It is true that the operation is not always successful but this chance is more than offset by the likelihood of a permanently stiff finger if surgery is not advised Unfortunately, this lesion is often not recognized for what it is, and operations to correct it are seldom performed or reported Until more information is available the indications for surgery will remain uncertain

Rupture and the partial rupture of tendons

Surgery for rupture and partial rupture of tendons is the only treatment for these lesions, but this is not always indicated Certainly the indications for operation are not the same as they are for the same lesions in the absence of arthritis This is because the disability is often slight compared with that due to other deformities already present, and because joint stiffness may hamper post-operative recovery One definite exception is rupture or partial rupture of the flexor pollicis longus tendon, for arthrodesis of the interphalangeal joint or tendon repair may restore useful function

PARAESTHESIAE

Tingling, painful tingling and pain have no clear dividing lines, either in fact or in the patient's mind As a result it is often difficult to know whether a patient

is talking about a symptom that probably arises in nerve tissue or one of the many symptoms that may arise elsewhere in the hand. Nevertheless, many rheumatoid patients have symptoms that are identical with those of idiopathic acroparaesthesiae. They complain of painful tingling and numbness in the hands, particularly at night. This is a common presenting symptom and it is common among the many symptoms that must be sorted out in the established disease. Unfortunately, it is seldom possible to make an anatomical diagnosis. Sometimes the fault appears to originate in flexor tendon lesions within the fingers, and the symptoms may disappear after an injection of hydrocortisone.

Occasionally, clinical and electrodiagnostic examination will indicate that the median nerve is being compressed within the carpal tunnel. It would be surprising if this were not so, since there are joints at the base of the tunnel and several tendons within the tunnel, all of which can become swollen by rheumatoid involvement. It is odd that acroparaesthesiae are seldom found when there is a gross flexor swelling at the wrist due to tenosynovitis.

Although tendon lesions and carpal tunnel compression may be diagnosed in a small proportion of patients, it is more usual to treat this symptom without the aid of a diagnosis.

Treatment

Use of the hand during the day often aggravates the paraesthesiae during the following night. Patients may learn to avoid certain activities such as knitting and potato peeling because they know these may be followed by a sleepless night, even if there is no pain at the time of the activity.

A short cock-up splint worn at night often relieves the symptoms completely. The response to this measure is unpredictable but it is always worth a trial.

Hydrocortisone can be injected among the flexor tendons at the wrist when it is believed that this may be the site of the symptoms. This procedure is not without risk to the median nerve. It is our practice to locate the nerve by electrical stimulation and then inject medial to the nerve and just proximal to the carpal tunnel. At times the results are excellent with lasting relief of symptoms.

Surgical division of the carpal ligament should be reserved for the small number of patients who have persistent symptoms due to carpal tunnel compression, and fail to respond to conservative measures. Electrodiagnostic tests should be performed routinely before deciding on surgery.

OCCUPATIONAL THERAPY

The use of occupational therapy for rheumatoid hands should be guided by the following general principles.

Patients with inflamed and painful hands

Such patients are often admitted to hospital for rest and treatment. Some are ordered complete rest, while others with milder inflammation do better if their hands are kept active. Otherwise, patients may spend the day with arms folded across their chests and their hands unused, apart from the brief periods when the physiotherapist is supervising formal exercises. It is this problem that the nurses and occupational therapists are expected to solve.

Light crafts and games are suitable for this purpose provided they involve

general activity of the hands with a minimum of strain on the joints The following principles are important.

(1) To avoid fatigue the work should be light and should employ objects that can be easily picked up and put down More elaborate apparatus is time consuming to set up and consequently work tends to be done in a few prolonged sessions with the patient struggling on long after she is fatigued

(2) Prolonged or firm gripping must be avoided Firm twisting is particularly undesirable

(3) Wrist flexion must be avoided at all costs This is mainly a question of placing the work at the correct angle For instance, a weaving loom must be tilted and not placed flat on the bedclothes If the wrists are particularly painful, they should be supported by light cock-up splints

(4) Free movement of the entire arm should be encouraged In this respect knitting is unsuitable as the elbows are usually tucked firmly into the sides

(5) Weaving, embroidery and basketry are the most suitable crafts To these can be added pastimes such as making a scrapbook, glass-papering, playing patience and solving wire puzzles

The restoration of function

As the inflammation subsides, treatment becomes more ambitious and aims at restoring full function This depends to a large extent on the patient's personality and the desire to do more Most do well by their own endeavours at home, but others, with less initiative or facilities, tend to let their disability overcome them Occupational therapy at this stage should aim to prove to the patient that her deformed hands are still useful, and to teach her how to use them efficiently It is best not to concentrate on individual deformities but to introduce general activities that have a purpose and are related to future work or personal activities The scope of treatment is almost unlimited, but special care should be taken to avoid prolonged gripping, wrist flexion and twisting Wheel grips on looms should be avoided as they put a severe lateral strain on the thumb and fingers Spade-handle grips are more suitable

When particular disabilities must be overcome, special attention is paid to them but not to the exclusion of all else Most crafts provide a variety of movements rather than simple repetition of an isolated activity, and it is best to accept this variety while teaching the patient to do the work in a way that will emphasize the important movement Following this principle, weak intrinsic muscles can be exercised by soap carving, lightweight tablet weaving, lino printing, modelling, leather work and similar activities Flexion of the ring and little fingers is essential in hooked rug-making, netting and plaiting Opposition of the thumb comes into stencilling, cutting out, cat's-cradle, solitaire, toymaking and the use of well-shaped handles

Severe permanent deformities

These present an entirely different problem to the occupational therapist The need is for an assessment of the deformities and considerable ingenuity in thinking out new ways of using the hand It is a matter of making the most of what little function remains

LABOUR-SAVING GADGETS AND SELF-HELP APPLIANCES

In recent years several hospitals have organized sections where patients can be taught how to overcome their disabilities The rheumatoid patient may benefit a great deal from this approach to her problems, but there are two major dangers to be avoided First, it should be remembered that patients in the early stages of their disease are often frightened that they will become crippled For them gadgets and appliances may be symbols of crippledom, and those who could be helped most may reject aid of this kind and become depressed by advice of the best intention Secondly, the wide medical and social implications of the disease must be considered It is worse than useless to hand out gadgets when the correct solution is a home help, a wrist support or a new job

The problems in the hand are principally concerned with carrying, gripping, twisting and fingering

Carrying is best reduced by reorganization of housework Firemaking is simplified by making the coals more readily accessible, and by using a long-burning fire and a gas poker, or by substituting an electric or gas fire Saucepans should be light and the larger ones should have two handles The lifting of saucepans

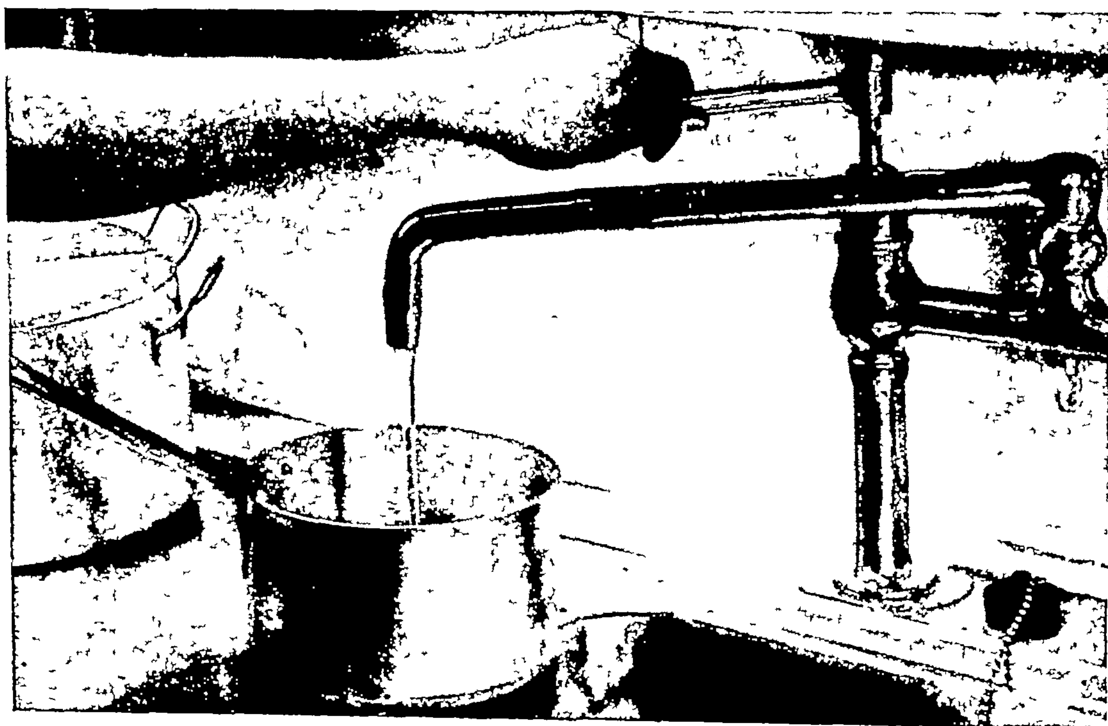


FIG 72—*Tap designed to facilitate the filling of a saucepan without having to lift it out of the sink when full*

after they have been filled can be reduced by having a tap with a long arm (Fig 72) Other lifting in the kitchen can be avoided by arranging the kitchen surfaces at the same height, or by using a trolley Ironing need not involve lifting if the iron is of the type that automatically tilts when released A teapot can be poured without lifting it if it is set in a circular holder

Gripping and twisting can be reduced by altering door handles to the lever type, and by using a special lever for turning taps An efficient wringer will help with the laundry

The handling and gripping of many objects can be made easier by increasing their size This applies particularly to the handles of knives and forks, tooth brushes, razors and combs Potato peeling, which is one of the activities that rheumatoid patients find most difficult, can be made easier by fixing the handle to a rigid support or by using a special potato peeler with a spade handle

Fingering difficulties affect dressing, sewing and knitting For easier dressing all fastenings should be made accessible by altering the clothes, buttons should be large or be replaced by zippers, and, in general, dress should be simple and not tight fitting

WORK

Although rest is undoubtedly the most useful form of treatment in rheumatoid disease, it is not always correct to rest and avoid strain on the hands This may be good for the joints but it is certainly not always in the patients' interests Their first concern is to get back to work or to the care of their families, and as long as this is not going to be detrimental they should be encouraged to do so The correct management of rheumatoid patients is always a compromise between the ideal and the practical While they are taught how to avoid unnecessary strain, they should also be encouraged to lead a life as near normal as possible This is essential for morale and helps to make pain more bearable

When advising patients about the work they should do, the nature of the hand deformities is seldom the deciding factor Other joint deformities and the prognosis are usually more important During the early stages of the disease it is best to make allowances for the fluctuations in severity, and aim to get a job well within the patient's physical capacity Otherwise they are likely to spend much of their time struggling against pain and fatigue Later, when the disease is more stable, they can work much closer to the limits of their ability The problem is then similar to that of resettlement after injury As always, the only way to reach an accurate assessment is to try the patient on a series of tasks under work conditions The combinations of deformities that may be present are too complicated to allow assessment from a study of the hand at rest

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CHAPTER 7

UPPER LIMB WEAKNESS

THERE are a number of conditions in which weakness or paralysis of some part of the upper limb cause inability to use the hand properly In some of these conditions the hand may itself be normal but the patient is incapable of using it because of the associated upper limb disability

This chapter is concerned with the main conditions under this category.

COMBINATIONS OF WEAKNESS

The following combinations of weakness are seen in practice

(1) The hand may be normal and either the shoulder or the elbow, or both, affected Examples of such conditions are poliomyelitis, a C 5 6 palsy, a C 5 6 7 palsy, and a paralysis of the elbow flexors and extensors, or elbow flexors alone

(2) The hand is partially affected and the shoulder or the elbow affected, or both Examples of this category are poliomyelitis, brachial plexus lesions, radial nerve palsy, and upper motor neurone affections such as hemiplegia.

(3) The hand is paralysed and the shoulder or the elbow affected, or both Examples of this group are again poliomyelitis, brachial plexus lesions, myopathies and motor neurone disease

With the exception of some cases of brachial plexus palsy, the third group is not amenable to conservative treatment as no amount of physiotherapy or splintage can provide function in a permanently paralysed hand Reconstructive surgery is, however, able to offer some worthwhile function if only to make the hand into a supporting member, but often some form of lively splintage to the wrist or the elbow can offer improved function in combination with reconstructive surgery

SHOULDER AFFECTIONS

There are many conditions which can cause weakness or paralysis of the shoulder, resulting in less efficient use of the hand The following are frequently met with in practice, affecting the function of the shoulder girdle muscles

Causes

Traumatic lesions of the brachial plexus causing upper trunk damage, resulting in either partial or complete paralysis of the spinati and deltoid, is one cause There may also be affection of the elbow flexors and the pectoralis major

These lesions are frequently traction injuries and have a notoriously bad prognosis However, a number of patients do get a surprising degree of functional recovery, and the tendency nowadays in Great Britain is to leave such patients at least one year before contemplating any reconstructive surgery Furthermore, it is possible to teach the patient compensatory movements, which will be described in detail later, to overcome deltoid paralysis

Paralysis of the deltoid itself is commonly seen, the most frequent causes being

circumflex nerve palsies following trauma, poliomyelitis and neuralgic amyotrophy

There are, of course, a wide variety of conditions that can cause wasting and weakness of the shoulder girdle These conditions include syringomyelia, amyotrophic lateral sclerosis, proximal myopathies, and high cervical disc lesions These may be combined with some hand affection, but their treatment does not differ in principle from the point of view of rehabilitation than in the permanent non-progressive affections such as traumatic nerve lesions and poliomyelitis

Treatment

Deltoid paralysis alone

There is a widespread belief that paralysis of the deltoid means loss of abduction of the arm In the last 60 consecutive patients seen with paralysis of the deltoid alone, or a combination of Teres minor and deltoid paralysis in a circumflex nerve lesion, every patient has regained full function, including full abduction and elevation against strong resistance without any recovery being seen in deltoid In every case the finding of clinical paralysis was confirmed by full electrodiagnostic tests The key muscles that must be present before this compensatory movement can be obtained are the external rotators of the humerus In the absence of the deltoid, abduction is initiated by the supraspinatus, if present, and carried to about 70 degrees by the long heads of the biceps and triceps At the beginning of abduction, the humerus is externally rotated by the infraspinatus At about 70 degrees the clavicular fibres of the pectoralis major act as powerful abductors because the axis of the shoulder joint has now rotated externally Thereafter, the serratus anterior elevates the arm through forward and upward pull on the scapula

It is our practice to teach patients this compensatory movement from the earliest stages after paralysis First, it is essential to restore passive movements to the shoulder joint if these are absent The re-education is carried out with the patient lying on his back and the arm supported in a sling with overhead suspension Before any attempt is made to initiate abduction, the patient externally rotates the humerus He is then asked to try to abduct the arm, and in so doing he will inevitably hitch up the shoulder by trapezius action The physiotherapist directs the patient's attention to this bad habit and encourages him to obtain the movement entirely at the shoulder A certain degree of swing is allowed at this stage to give the patient the idea of movement When the first few degrees are obtained the patient is encouraged to think about each group of muscles, first the biceps and triceps, then the pectoralis major, and finally the serratus, throughout the various stages of movement All the time he must keep the humerus in full external rotation if possible As soon as the patient loses the hitch it will be found that the range increases rapidly

In a small number of patients difficulty may be found in learning this trick. In these cases it is helpful to give specific resistance exercises to the long heads of biceps and triceps, and to break down the movements into isolated ones in each muscle involved This is particularly helpful in poliomyelitis when there is associated weakness of the other muscles, such as the biceps and pectoralis major.

As the patient improves, the treatment couch is gradually inclined at an increasing angle so that gravity resists the movements more and more A light weight of about 1 lb helps the patient to initiate and hold the movement

The patient should watch his movements in a mirror in order to get the normal scapulo-humeral rhythm restored at an early stage In difficult cases, and particularly where there is much joint stiffness which might follow poliomyelitis or a shoulder dislocation with circumflex palsy, re-education in a warm pool is most helpful

The length of time required to learn these compensatory movements is approximately 4–6 weeks In a good patient, however, this may be very much shorter, and the quickest success we have ever had was in a patient who sustained complete paralysis after shoulder dislocation Re-education started 4 weeks after injury and he had regained full movement in all ranges at the end of a half-hour session in the physiotherapy department It must be stressed that these movements providing full abduction and elevation are not trick actions in the sense usually associated with this word, all the muscles involved normally help to abduct the shoulder The scapulo-humeral rhythm is quite normal, and in the later stages of re-education the patient does not even need to rotate the humerus externally to initiate the movement Furthermore, the power of abduction becomes by the end of treatment quite as strong as the normal side, and many of our patients have returned to full duty and have been enabled to manage the most arduous of tasks Fig 73 shows the movements in a patient with a paralysed deltoid

It has been found that about 20 per cent of these patients at follow-up had eventual recovery in the deltoid, but it was not possible to distinguish by power and by general function those that had from those that had not

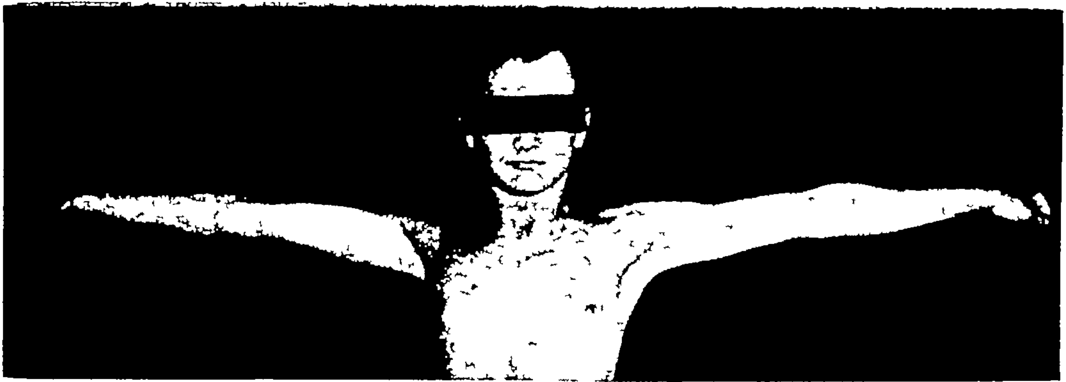
If the deltoid begins to recover during re-education, paradoxically the rate of progress in learning these movements slows down It seems as if the body cannot cope with the two slightly different movement patterns at the same time

It is our firm opinion that no purpose is served by not teaching patients to learn these movements as early as possible, irrespective of whether they are likely to get recovery in the deltoid or not Recovery of maximum function as soon as possible is the aim of rehabilitation, and experience has shown that no possible harm is done in teaching these movements to patients who ultimately recover full deltoid action We have yet to see a patient with deltoid paralysis, with or without Teres minor paralysis, who has not been able to regain full function by learning these movements

Deltoid paralysis and involvement of other shoulder muscles

When other muscles in the shoulder are affected, re-education is much more difficult In the presence of complete paralysis of the infraspinatus, it is not possible to teach this action If the paralysis remains permanent it is worthwhile considering reconstructive surgery once all hope of regeneration is passed The principle of surgery here is to enable the compensatory movements described above to be used by transferring the internal rotators to the back of the humerus so that they act as external rotators Provided the patient has the long head of biceps and pectoralis major, he will be able to abduct the arm It is obviously an operation that is only done on rare occasions, but if the patient is prepared to work really hard, the results are well worthwhile

It is not uncommon for patients to be seen with paralysis of the infraspinatus A surprisingly small amount of muscle in the infraspinatus needs to be working for the patient to be able to abduct the shoulder A number of patients have



(*a*)



(*b*)

FIG 73 —*Paralysis of right deltoid* (a) *Abduction at 90 degrees* (b) *Full elevation*

been seen who, at the commencement of treatment, were unable to abduct their shoulder at all, and who had paralysis of the infraspinatus, as well as the deltoid, due to traction lesions of the brachial plexus Electrical investigations showed that there was definite activity in the infraspinatus, and accordingly re-education was started

In a matter of 4–6 weeks good abduction resulted This is carried out while the patient is lying on his back with the arm supported in a sling in suspension Gentle rotary movements of the whole arm are encouraged first Next the arm is bent to a right angle and held by the physiotherapist with the elbow right into the side and the forearm supinated The patient is then encouraged to rotate the humerus externally, the physiotherapist giving very slight resistance at the lateral aspect of the mid-forearm and supporting the scapula posteriorly, feeling for the muscle contraction at the same time By this means the physiotherapist can tell if the patient is tricking the movement or if he is genuinely using his infraspinatus Sessions of 6–8 attempts are interspersed with the same action on the normal side so that the patient then feels the correct movement

Pattern re-education of all arm movements is carried out at each treatment

session This includes forward flexion with the elbow flexed and extended, and swinging movements with the patient standing and the trunk flexed

The use of proprioceptive facilitative techniques are valuable in re-education of shoulder function

The principle of this technique is to bring into action muscle groups whose motor nerve cells adjoin those of the weak muscle in the spinal cord and by irradiation coax them into action The following manoeuvres are carried out

(1) Patient lying in prone position The patient pulls the shoulder and arm posteriorly and inwards, drawing the scapulae together Resistance is given to the whole arm by the physiotherapist If the patient is too weak to produce significant movement (for example, as in a brachial plexus palsy) resistance is given to the neck, and the patient is asked to extend the neck as he tries to pull back the shoulder and arm

(2) Patient lying in prone position. The patient rotates the arm inwards, at the same time pulling the arm back and the scapulae inwards as before

(3) Patient lying on his back The elbow is held firmly into the side at 90 degrees The patient then tries to rotate the humerus externally, feeling for the infraspinatus contraction himself The physiotherapist gives resistance, stabilizing the shoulders by pressing down on them on the plinth The patient next crosses his arm over his body, the wrist and fingers being fully flexed The patient then brings the arm across in an arc away from the body in an extensor thrust, the fingers, wrist, elbow and shoulder all being extended maximally against the physiotherapist's resistance throughout, a final hard resistance being given as the movement is completed

(4) When the elbow flexors and pectorals are weak, the reverse manoeuvre is used

The arm is held extended fully at all joints, wrist, fingers, elbow and shoulder, and in external rotation The patient pulls the arm across the body against resistance in a flexor thrust, aiming for the forehead

(5) In addition to the special techniques outlined above the general principle holds that any muscle that crosses a joint can be made to move that joint whether that is its prime function or not Hence, muscles crossing affected joints are re-educated as synergists, with and without resistance, until eventually they can be urged to act as prime movers

Case 1 Patient R J B was involved in a road accident 14 9 56 He sustained a traction lesion of the right C 5 root, resulting in paralysis of the supraspinatus, the infraspinatus, and the deltoid, and sensory loss over the lateral aspect of the lower part of the upper arm In addition the right scaphoid was fractured Rehabilitation commenced 1 week after injury Passive movements to the shoulder, electrical stimulation to the affected muscles and general arm exercises were given

Electromyography (13 10 56) showed complete paralysis of the deltoid, but a partial lesion only of the infraspinatus—many discrete normal motor unit potentials being seen against a background of fibrillation

Re-education was started in earnest in the hope that enough of the infraspinatus was working to enable compensatory movements to be successfully taught Treatment was complicated by the fact that the patient had the weight of the scaphoid plaster to work against on the affected side

Within 2 days the patient could raise the arm above the head when lying down, 29 days after injury he could abduct to 40 degrees in a standing position

Two months after injury (14 11 56) he was able to abduct and elevate the arm with ease, despite the complete paralysis of the deltoid The scaphoid plaster was removed 11 weeks after injury

The patient was discharged to storeman's duties 6 2 57, nearly 5 months after injury, with very strong power in the right shoulder, but the deltoid remained paralysed The only detectable weakness was lack of full power in extension and forward flexion

It is worth encouraging all patients with severe shoulder weakness or paralysis to learn the arm fling, this manoeuvre consists of the arm being swung briskly across the front of the body and relaxed very quickly, so that the momentum and the extra pull provided by the pectoralis major brings the arm above the head The fling is useful to learn both for lifting light objects from the shoulder above the head and as good pattern re-education for the early stage of recovery

Serratus anterior weakness

Paralysis of the serratus anterior occurs after trauma, particularly traction injuries to the upper limb and the long nerve of Bell is vulnerable to serum neuritis It can, of course, be involved with the other muscles in traction lesions of the plexus, poliomyelitis and myopathies

When the muscle is completely paralysed, disability is severe because the scapula cannot be rotated and, therefore, abduction is difficult above 90 degrees It is, therefore, not generally appreciated that only a slight degree of serratus action is required for good function in the shoulder to be possible

ELBOW AFFECTIONS

Causes

The flexors of the elbow joint can be affected in brachial plexus lesions, poliomyelitis, and in lesions of the musculo-cutaneous nerve It is rather uncommon to find isolated paralysis of the elbow flexors only, usually there is some weakness of the deltoid and spinati, such as would be expected from lesions of the C 5 root, or affections of this part of the cord in poliomyelitis A similar distribution of weakness is found in proximal myopathies These often do not involve the hand and the problem then becomes one of offering the patient some form of lively splintage to put the hand and elbow in the position of function

Treatment

When the elbow flexors are affected, and not only flexion of the elbow is weak but also supination due to the biceps being involved, the brachio-radialis is capable of acting as a powerful flexor provided it is given appropriate training The muscle will flex the elbow most efficiently when the forearm is in the position midway between pronation and supination (Fig 74)

At the start of training the elbow is put in 90 degrees flexion or more, the forearm into the neutral position, and the patient encouraged to bend the elbow using the brachio-radialis As soon as the patient has an idea of the movement, resistance is added, first from the physiotherapist's hand, and later using a progressive resistance technique with weights It has been found that the most satisfactory way of retraining the brachio-radialis and developing its power quickly is to give the patient a table of exercises in which he is asked to lift an increasing load an increasing number of times On the first day of weight exercise, the patient may be able to raise 1 lb from the full extended position of the elbow to the maximum

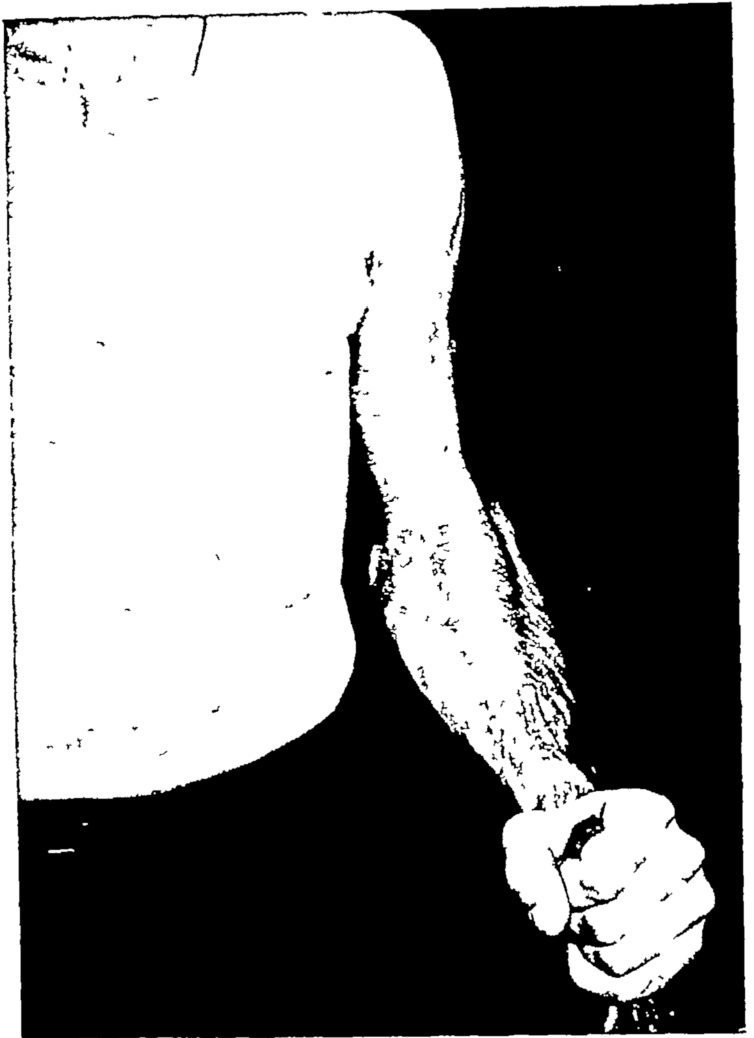


FIG 74 —*Lesion of musculocutaneous nerve Flexion of the elbow carrying a 5 lb weight using brachio-radialis*

range of flexion, 5 times, thereafter the number of times the weight is lifted is increased When the patient can raise the weight 20 times, it is increased to 2½ lb, and when this can be lifted 20 times, it is again increased Progression depends entirely on the rate of progress in the weight raising exercise, but the principle is to develop strength and endurance at the same time, for the elbow flexors are required not only to lift weight but also to maintain the forearm and hand against resistance over a period of time

If there is associated weakness of the other C 5 muscles, the arm cannot be given the stability required of it by the deltoid and spinati to allow the brachio radialis to carry out its tricks In these circumstances the patient hyperextends the wrist and fingers adducts and the shoulder into his side, thus bringing the arm across the body, the brachio-radialis will then flex the elbow In a few patients it is possible to develop the power of these movements sufficiently to carry out simple tasks such as doing up buttons, but in general this trick action is not sufficiently powerful to be used functionally When reinforced by a lively splint, it is extremely useful In some patients it has been found that after wearing a lively splint to give elbow

flexion for 3 months, the power of brachio-radialis is so strong as to give practically normal function

WEAKNESS OF TRICEPS

Paralysis of the triceps can result from posterior cord lesions, poliomyelitis and myopathies, severe weakness is a common complication of fractures of the elbow, particularly the olecranon

The operation for shortening the triceps following olecranon fractures is often undertaken to correct severe weakness of this muscle, but this in itself does not obviate the necessity for intensive redevelopment of the triceps power both before and after operation In mild cases it may not be necessary to operate if the exercise programme has been successful, but if there is any degree of triceps weakness, operation is advisable Extension of the elbow is, of course, carried out by gravity as well as by the triceps Unless this is remembered quite severe degrees of weakness can be missed clinically When the patient is asked to extend the elbow from full flexion with the shoulder at 90 degrees forward flexion, it will be seen that the shoulder drops forward so that gravity can allow the elbow to extend If the elbow is watched carefully, it will be seen that there is no actual movement in the joint until the shoulder has dropped to less than 45 degrees If slight resistance is given against the forearm, the trick shoulder depressor action is clearly seen

When testing the triceps clinically, the angle of shoulder flexion at which the elbow can just be extended should be noted To test this, the patient is asked to raise the arm above the head so that the elbow is fully flexed The examiner supports the shoulder at gradually decreasing degrees of elevation until the patient can just extend the elbow—this angle is measured and as the triceps increases in strength it becomes greater The examiner prevents trick action by his support Appreciation of the trick action of the shoulder depressors is important for the occupational therapist and the physiotherapist

It is easy to set up a craft and give progressive resistance exercises, the main effect of which is to build up the power of the depressors and not the triceps at all

When the shoulder is abducted to 90 degrees and the elbow flexed, elbow extension should not be possible in the presence of complete triceps paralysis A few patients have, however, been seen in which undoubted triceps paralysis was present, yet good extension of the elbow was possible in this position Here the wrist extensors and brachio-radialis were the muscles responsible Re-education is therefore well worth trying in patients with triceps paralysis

As in all re-education programmes, resistive exercises to the muscles responsible are given in their normal range of movement, when the patient has the idea of the compensatory action they are trained in the new range

Compensatory or trick actions, provided that there are muscles to stabilize and fix the joints involved, can usually be taught in a co-operative patient, and can often provide sufficiently good function If the joints cannot be stabilized due to extensive weakness or paralysis, then compensatory activity can only be expected to assist other devices, such as splints, or to give fair function such as the arm fling Should reconstructive surgery be considered, it is well worth aiming at maximum function with whatever compensatory activity can be obtained, before operation For example, in an extensive brachial plexus lesion, if bone block to the elbow,

arthrodesis of the wrist, and tenodesis of the fingers are planned, it is a good thing to encourage the patient, before operation, to develop whatever movement and function he can at the shoulder joint, which will, after operation, offer increased function

There are very few indications for avoiding trick movement where function is the aim The only real need to avoid trick movements is during treatment when the normal muscle groups may be being improved by exercise at the expense of the affected groups, the best example being the case with which shoulder depressors will substitute for the triceps

PRINCIPLES OF RE-EDUCATION

It is well known to physiologists that only 20 per cent of the available motor units are used in a maximal contraction Sharrard (1955) showed that a Grade 3 muscle on the Medical Research Council scale following poliomyelitis had only 5–10 per cent of its motor cells left in the spinal cord

It can thus be seen why muscles that are clinically very weak and show electromyographically only a few motor unit action potentials are yet able to afford excellent function

The lesson to be learnt is that despite very little clinical activity it is always worth initiating a programme of re-education This is particularly true in the upper limb where weight-bearing is not a requirement

Even though there may be extensive weakness of the prime mover it is worth attempting re-education and development of trick actions The examples quoted above of severe infraspinatus weakness with deltoid paralysis and severe serratus weakness showed what good function can be obtained after retraining despite an apparently hopeless situation

The principles of re-education are the same whatever muscle groups are involved In summary they are as follows

(1) To restore full passive movement to the joint

(2) To inculcate the idea of the movements required on the normal side and passively on the affected side

(3) To encourage the patient to work the muscles that are going to effect the compensatory activity in their normal role first, and build up their power by resistance exercises

(4) To encourage the patient to carry out the new movements at first in the inner range with full support, at the same time avoiding all unwanted actions for example, the shoulder hitch must be avoided when re-educating shoulder abduction

(5) Having worked out the mechanics of the compensatory actions required, the joints involved are put in the best position for offering function so that the axes of the joints are aligned in such a way that muscles not normally acting as prime movers can do so

(6) The session of treatment should last at least half an hour, and can usefully be preceded by any form of physiotherapy, such as heat, which relaxes the patient

(7) Two or more sessions a day are best for a quick result Treatment in the

occupational therapy department and in the gymnasium should be devised for general function of the limb, and where possible, to reinforce the physiotherapy Any form of unwanted movement must be avoided at all times

LIVELY SPLINTS

When adequate function cannot be obtained by utilizing compensatory actions, some form of artificial aid will be required It is in this field that lively splintage offers useful function The principles of such splintage are to provide function by stabilizing joints to allow available muscles to act more efficiently, and by the use of springs to substitute for paralysed muscles It is a *sine qua non* of lively splintage that the splints should be constructed in such a way that the patient will wear them, meaning that they must be made with the patient's particular job in mind Wherever possible they should be made actually on the job, so to speak, so that the required range of movement can be accurately provided Furthermore, they must be as light, as simple, and as inconspicuous as possible, they must be cheap, easy to clean and easy to alter The splints to be described, in our opinion, fulfil all these criteria Full details of their manufacture are given in the appendices at the end of this chapter

Once made, the patient should be asked to wear the splint and report at the end of one week, when the fault should be noted and alterations made Two or three fittings are required because the patient learns new function once he has the splint

Splint for elbow extension

Although gravity will allow elbow extension, the real disability of a patient with severe triceps weakness is the lack of stability in the elbow in any position of flexion The following lively splint overcomes this difficulty

As for the flexion splint, there are upper arm and forearm pieces hinged at the elbow, but here the spring aid is posterior to the axis of the joint (Fig 76)

Splints for elbow flexion

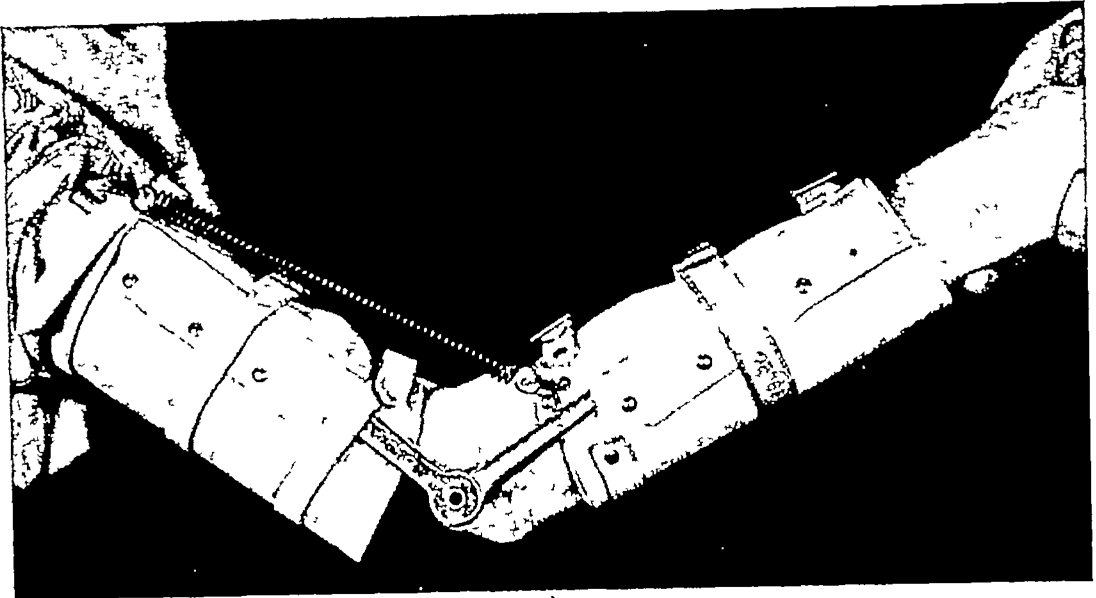
This splint is devised to give a useful degree of elbow flexion It comprises two leather pieces, one on the upper arm and one on the forearm, hinged at the elbow and with an interior spring to substitute for paralysed or weak flexors (Fig 75)

When both elbow flexors and extensors are paralysed a splint is provided which consists of upper arm and forearm leather pieces joined by a hinge at the elbow This hinge has a stop device allowing the elbow to be fixed in one of four positions, thus affording a functional range of positions in which the elbow can be fixed (Fig 77)

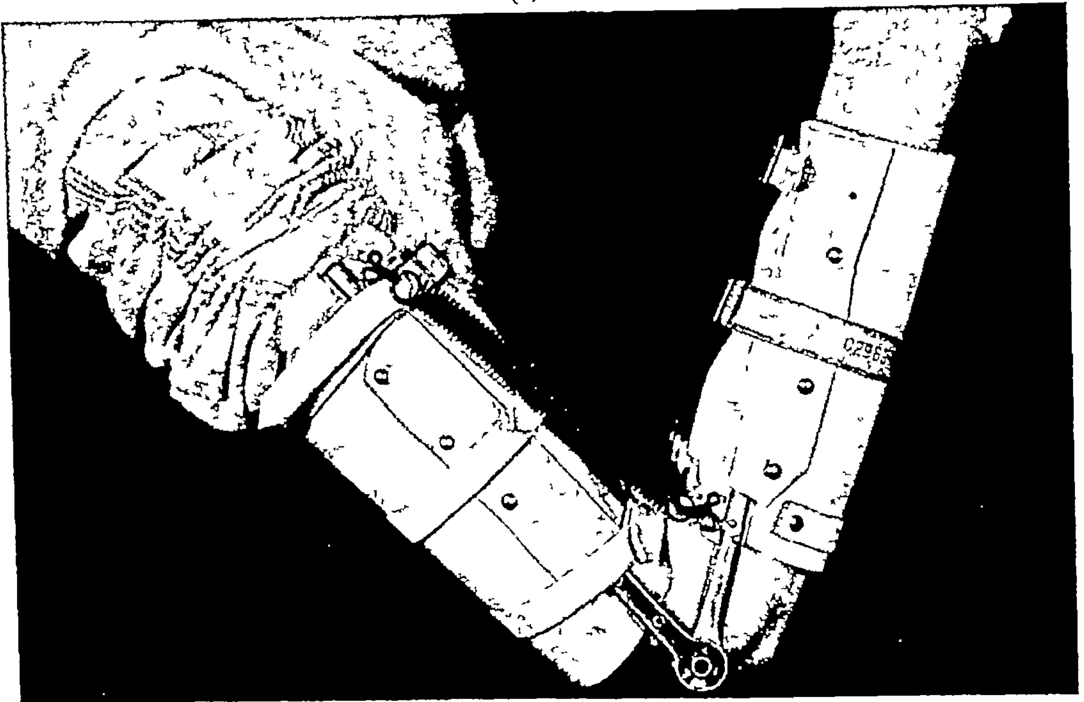
For patients with good extensor power of the elbow but weak flexors, a small splint with leather upper arm and forearm pieces is provided with an anterior spring allowing the patient to maintain a flexed position of the elbow (Fig 78)

Splint for elbow paralysis and wrist drop

The common pattern of involvement is for the elbow and wrist and finger extensors to be paralysed, the commonest examples in this condition being poliomyelitis and lesions of the brachial plexus involving C 5 6 and 7 , in such a condition the intrinsic muscles of the hand are normal and, therefore, the two main important activities of the upper limb, opposition and grip, are available, but



(*a*)

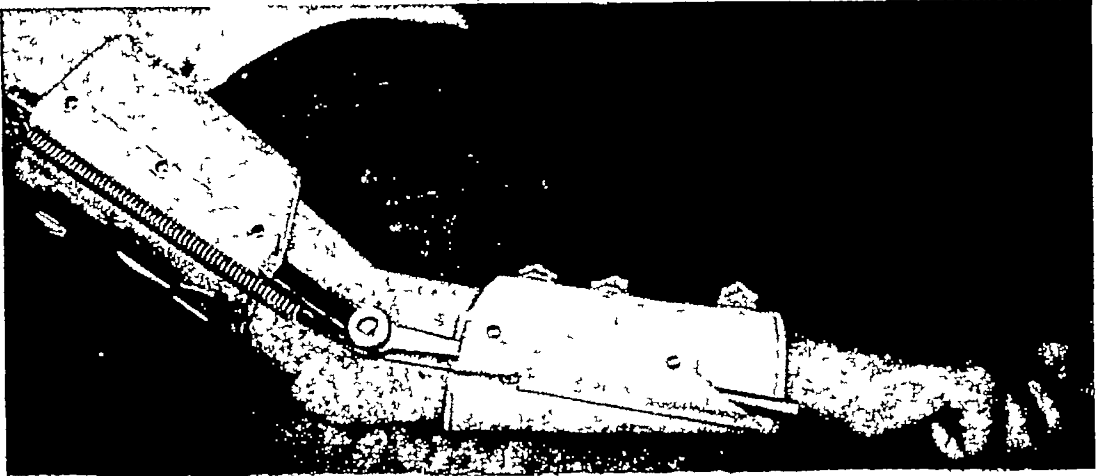


(*b*)

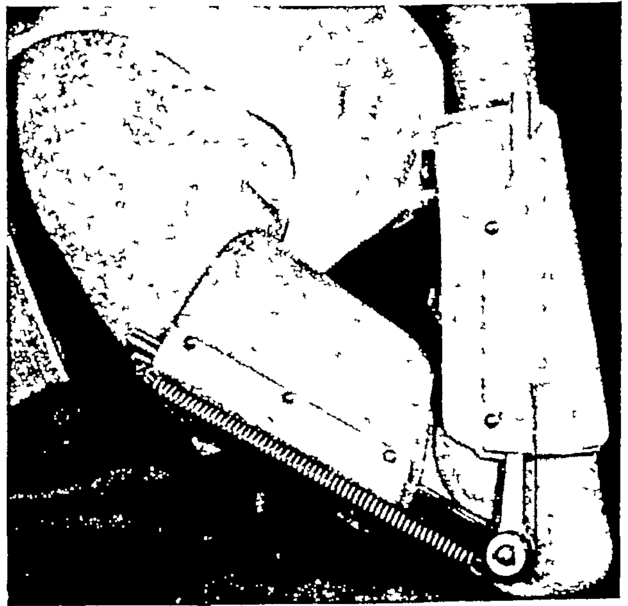
FIG 75—*Lively splint for paralysis of the elbow flexors* (a) *Extension* (b) *Flexion*

cannot be used effectively as the patient is unable to put the arm into the position of function, that is, flexion of the elbow and extension of the wrist

The lively splint for this condition allows flexion of the elbow and spring extension of the wrist The upper arm and forearm pieces are attached in this splint by a strap and buckle which can be adjusted to give the required amount of flexion The upper arm piece has a shoulder attachment strapping round the chest to prevent subluxation of the shoulder It is made in such a way that the patient can alter this by putting his hand inside his jacket There is a hinge at the wrist joint



(*a*)



(*b*)

FIG 76 —*Lively splint for paralysis of the elbow flexors* (a) *Extension* (b) *Flexion*



FIG 77 —*Lively splint for paralysis of the elbow flexors and extensors The patient can adjust the elbow to one of four positions by pressing the spring stop*

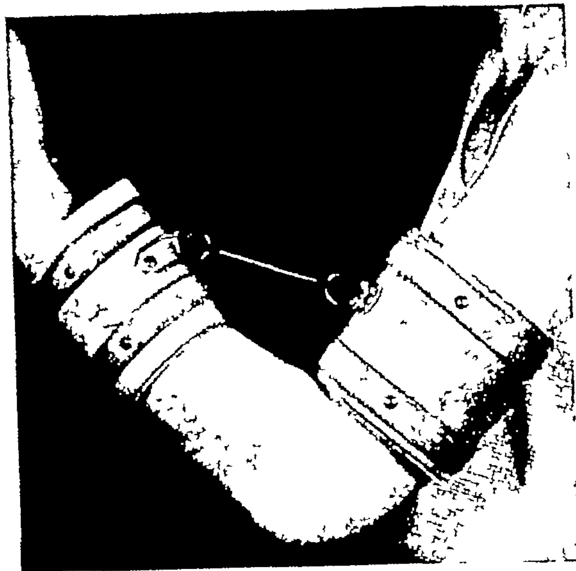
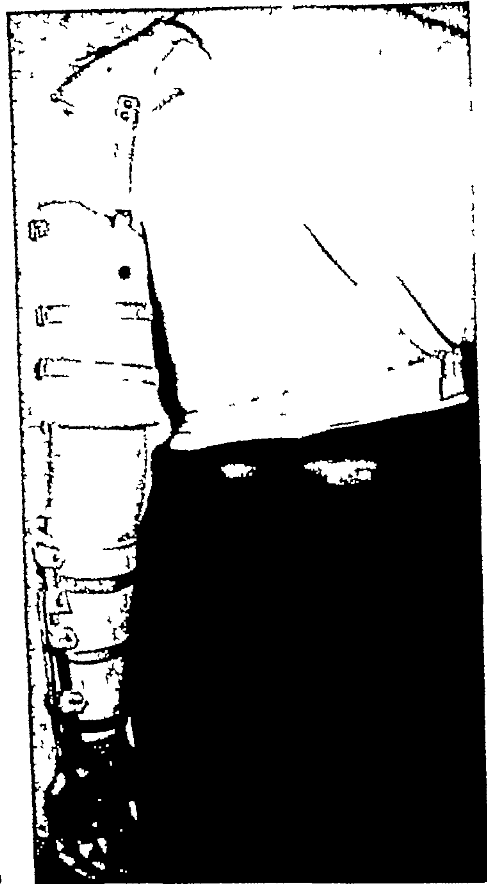


FIG 78 —*Lively splint allowing a patient with weak elbow flexors to maintain a flexed position*



(*a*)



(*b*)

FIG 79 —*Lively splint for patient with C 5 6 7 palsy The patient can adjust the position of the elbow with the strap, and there is a spring hinge allowing extension of the wrist (a) Flexion (b) Extension Note the shoulder pad*

controlled by a spring lying along the lateral border of the forearm bringing the wrist into extension (Fig 79)

The alternative to this splint, surgically, is a bone-block to the elbow with either spring extension to the wrist, as described above, or arthrodesis of the wrist

There are certain disadvantages to the bone-block of the elbow, in some patients the bone resorbs, and most patients do not like the fact that their elbow is permanently flexed, making it impossible in some cases to put their hand in their pocket

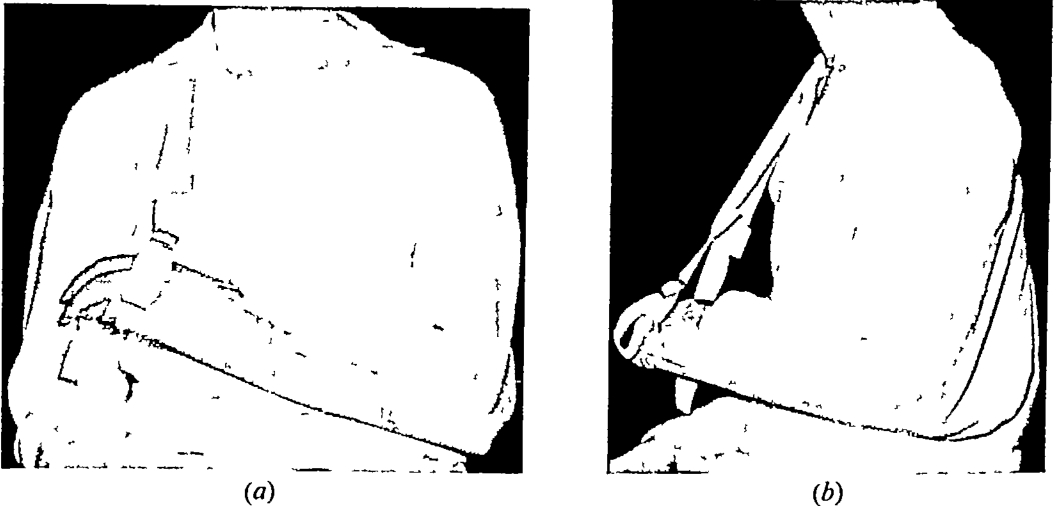
We feel that the flexion offered by this splint is a real advantage and offers both stability and a satisfactory cosmetic result

GENERAL AFFECTIONS WITH RESULTING HAND WEAKNESS

There is a wide range of conditions which produce weakness or paralysis of the hand muscles due to general conditions or lesions outside the hand The commonest practical problems presented by such conditions are weakness of the hand, due to cord lesions such as motor neurone disease, vascular accidents and syringomyelia, root lesions, such as osteoarthritis, cervical disc lesions and tumours, and primary muscle conditions as in the various types of myopathy

It is obvious that the prime cause must be treated, and it will be inappropriate to discuss this any further in such a work, but the principles of treatment of weak muscle already discussed are just as applicable to the permanent weakness or paralysis left by such conditions Weakness of the thenar muscles in a myopathy, for example, can be helped by the provision of an opposition lively splint Again, weakness of the elbow flexors in proximal myopathies can be helped by the flexion splint already described

It is advantageous to teach trick actions wherever possible, even though the condition is expected to deteriorate, hence, in a patient with motor neurone disease there will be every reason for teaching trick action to flex the elbow or to abduct the shoulder



(a) (b)

FIG 80 —(a) *Front view and* (b) *side view of sling used for resting the upper limb*

The problem of spasticity affecting the hand is perhaps the most difficult of all After hemiplegia which is anything more than transient, recovery of independent action of the intrinsic muscles of the hand cannot be expected Maximum function, however, can be obtained by encouraging all available activity in the limb and by the provision of lively splints to the hand, adaptation of tools, household appliances, and so on The great enemy of function in hemiplegia is oedema of the hand with subsequent stiffening of the joints

It is vital to maintain as full a range as possible in all joints of the upper limb Elevation of the arm in the early stages of recovery may be required for several hours a day

The sling illustrated in Fig 80 has been devised to solve this type of problem It consists essentially of a canvas sling in which the arm rests fully supported, and in which the position of the forearm can be varied by adjustable straps and buckles The hand can thus be elevated to the required degree

As intrinsic action will not return, compensatory movements must be encouraged Provision of an opponens lively splint will, for example, improve the grip

Most important of all is the provision of appliances for the hand rather than any attempt to develop function of the hand to use normal appliances

CONSTRUCTION OF SPLINTS

Splints for Brachial Plexus Lesions (Fig 79)

Indications

This splint is commonly used in poliomyelitis

Principles

(1) It is important that a patient should be enabled to use the remaining function of his hand, but this is virtually impossible if he has lost the power to flex the elbow Some means must be found whereby he is able to bring the hand into the required position

(2) It is also important that activities should be started as soon as possible, even though reconstruction may be contemplated

(3) If the prognosis is good, use of the affected hand will save the patient from becoming habitually " one-handed " in habit

(4) The ability to use the hand, even with limitations, helps the patient's morale

Function of the splint

The splint is designed to bring the elbow into varied degrees of flexion, and to correct the tendency to subluxation at the shoulder joint

Method

Materials required

Firm tanned hide, 1 strap 20 × ¾ inches, 6 straps 15 × ⅝ inches, 3 buckles of ¾ inch roller type, 6 roller buckles of ⅝ inch, 2-bar, rivets, twine, chiropody felt, roll of 1 inch white webbing, wrist hinge, springs

The splint consists of a gauntlet, an upper arm cuff and a kidney-shaped shoulder cap

Forearm gauntlet

The measurement and construction of the forearm gauntlet is exactly the same as for the splint for radial nerve lesions (Chapter 3) with the following additions A ¾ inch buckle is attached at the wrist with the prong and roller facing towards the elbow, this is fixed on the palmar aspect to bring the hand into 30 degrees of supination

The second buckle is prepared as follows the prong is removed carefully without damaging the roller, the middle bar and the roller are left intact, but the third bar is cut off close to the middle bar A piece of leather is cut to slip round the middle bar and fold under, and the two layers of leather are riveted close to the bar on the dorsal aspect of the gauntlet, close to the elbow crease

Upper arm cuff

Measurements necessary are round the upper arm close to the axilla, and round the lower arm just above the epicondyles The length is from these two points plus 1½ inches The straps are added in the method already described but to the following distances the elbow strap 1 inch from the edge, the middle one centred, and the axilla strap 1½ inches from the axilla border

The opening for this cuff is over the lateral aspect of the humerus

The lining is cut and the cuff fitted and marked

Fitting and marking

The cuff is fastened on to the patient and should be firm but not too tight, and excess width is cut away on the edge of the insertion straps A deep curve is cut from the insertion of the pectoralis major, under the axilla to the posterior axillary fold This is to avoid friction and pressure under the arm With the forearm gauntlet in place, the elbow is flexed and, again, a curve is cut in the fold of the elbow to allow the two cuffs to come together without pinching the skin

Fixing and marking the long pulley strap

The axillary end of the strap is split to 3 inches in length One side is marked and riveted just over the anterior triangle, the second piece is riveted at about the point of insertion of the pectoralis major so that the split opens out into a "V" The object of this is to distribute the weight which this area will have to carry, and the position of the first riveting is to pull the weight away from the area of the vessels passing through the axilla and so reduce pressure at this point The riveting should be done through the top strap circling the arm The strap is then passed through the loop at the elbow and into the buckle at the wrist

The kidney shoulder piece

This is best marked on the patient himself The concave piece should lie round the base of the neck and enclose the whole of the area of the shoulder joint The principles of construction aim to fix the shoulder cap in place, from the waist on the opposite side of the affected arm and a counterpull from the centre of the deltoid edge to the lateral upper arm cuff This should keep the cap in place and prevent it slipping and pressing at the base of the neck The pull upwards of the humerus into the glenoid cavity is through two straps from the cap downwards to the humeral cuff aided by the lateral strap This is a delicate operation of balance and undoubtedly needs some practice As there is approximately a 10 lb pressure over the deltoid area, the cap must be very well padded, and it is advisable to wait until all tenderness has disappeared before using this technique

Construction

Prepare and fit a firm leather belt to waist size, slightly pad and line with chamois leather On the side of the belt opposite the affected arm fix a loop about 2 inches in length Cut out the shoulder piece and on it stitch a piece of the webbing long enough to pass across the back of the shoulders, through the loop at the waist, returning across the chest to a buckle fixed on the anterior portion of the cap One loop is usually enough for a male, but for a female two loops must be added, one at about the tip of the last rib and the other at a point near where the elbow touches, the loop must be adjusted so that the strap passes between the breasts

The webbing will be fixed on the posterior aspect of the cap towards the neck

and following the direction it will lie across the back The buckle is fixed on the anterior aspect of the cap at a point near the middle third of the clavicle, and also lying in the direction of pull towards the waist loop A $\frac{3}{8}$ inch strap, approximately 6 inches in length, is riveted over the mid-line of the deltoid edge

Marking and fixing the cap to the splint

Assemble the whole splint on the patient With the cap in place pull the deltoid strap down over the humeral cuff and mark the position of the buckle to receive it

Marking the counterpull straps

In a direct line from the acromio-clavicular joint to the anterior aspect of the humeral cuff and $\frac{3}{4}$ inch from the edge, rivet a $\frac{5}{8}$ inch strap marking the corresponding point on the cuff for the buckle to receive it (this should fall near to the long strap outside the rivet position) Similarly, the posterior strap is positioned from the acromio-clavicular joint to the axillary fold and the position of the buckle marked on the posterior aspect of the humeral cuff Small $\frac{5}{8}$ inch buckles are used to receive the straps and are fixed in the same way as for the gauntlet buckles The cap is then lined with $\frac{1}{4}$ inch chiropody felt and additional padding if necessary The lining of the cuff is stuck in, allowing enough to turn over the top of the curve made for the axillary space A piece of jaconet is placed over this dip and lightly stuck down with rubber solution The jaconet can be changed when necessary

ELBOW SPRING SPLINT (Fig 75)

Indications

These splints are of value in brachial plexus lesions involving C 5 6 7 and in poliomyelitis

Principles

The following principles apply to the use of the elbow spring splint

(1) To supplement loss of flexion of the elbow thereby bringing the hand into a functional position

(2) To allow active use of the triceps as the controller of the spring flexion

(3) To give constant active exercise to the elbow extensors

(4) To enable a patient to resume his own work, if possible, or to go on to retraining at the earliest possible moment

Method

Materials required

Tanned hide, chiropody felt, 20 lb nylon fishing line, 6 buckles of $\frac{5}{8}$ inch, 6 straps $\frac{5}{8} \times 15$ inches, 1 elbow spring hinge, springs, rivets, press studs

Measurements and fitting

This is as for the brachial plexus gauntlet and upper arm cuff with the following differences (1) the opening for the cuff lies between the full fold of the flexed elbow and the medial epicondyle, so that it does not rub over the chest wall or interfere with elbow flexion, (2) the only addition to the upper arm cuff is a strip of hide the length of the cuff and stitched in line with the posterior border of the acromion process and lateral epicondyle, 2 inches in width The forearm gauntlet is made as for the radial splint

Fitting the spring hinge

With the elbow held in flexion the two arms of the hinge are placed up against

the leather strips which are to receive them, with the hinge over the space felt between the head of the radius and the lateral epicondyle Using a scriber the metal is marked to the length of the gauntlet and cuff, and the surplus metal cut off At each end of the bar two ⅛ inch holes are drilled 1 inch apart Each end of the bar arms is secured to the leather cuffs by the nylon thread, passing the thread about 5 times through the holes of the bar and corresponding holes made in the leather Sections are cut from the strip encasing the bar where the hooks receive the spring The strip is then moulded firmly over the bars The strip is riveted in place as near to the bars as possible, a rivet lying on either side of each hook

Both parts of the splint are lined with chiropody felt The axillary curve is covered with the jaconet, and the press studs fixed to the end of the straps to secure them as described

Variations in springs

(1) If flexion is entirely absent, the spring will need to be strong enough to carry the weight of the lower arm into the position required

(2) If, as sometimes happens in poliomyelitis, there is some active flexion, the strength of the spring can be used as an assistant to the muscle to encourage its use

If flexion is poor in power and difficulty is found in maintaining the position in order to carry out the patient's own job, the spring needed will be as (1), but active work of the flexors will still be maintained, as the extensors are working against resistance

Brachial Plexus Spring-stop Splint (Fig 77)

Indications

This splint is used in extensive or complete brachial plexus lesions and in poliomyelitis (flail arm)

Principles

The following principles apply to the brachial plexus spring-stop splint

(1) To enable the forearm and hand to be used for stabilizing, as assistant to the active arm

(2) When the long flexors to the hand are intact, to enable them to be used actively

(3) When some functional use of the hand has been achieved by reconstruction operation, but there is no elbow movement

Method

The construction of this splint is the same as for the elbow spring splint with the addition of the shoulder cap as for the Type 1, brachial plexus splint, to counteract the tendency to shoulder subluxation

Additional construction

A round pad is fixed to the back of the hinge joint, suspended from the bar just above it, so as to make it comfortable for the patient as he presses the spring to release the spring stop A light alloy " cock-up " splint is incorporated in the gauntlet by drilling small holes into the forearm piece and stitching it to the gauntlet The handpiece is slightly padded and covered with a light gloving or chamois leather The forearm piece will be covered when the lining is placed within the gauntlet

Using the spring stop

To use the stop the patient passes the active hand under the flail forearm, lifting it forward, and the stop is then pressed against the elbow which releases the hinge and allows the active arm to place the elbow in the required position The same procedure is used to drop the arm into extension

SMALL ELBOW FLEXION SPLINT (Fig 78)

Indications

The small elbow flexion splint is used in weak triceps (as after trauma or poliomyelitis), weak elbow flexors, and brachial plexus lesions involving C 5 6 7

Principles

Construction of the splint should incorporate the following points

(1) To give constant resistance to the triceps when power has been reduced

(2) To enable a patient to carry out his normal work involving constant elbow flexion if the flexors are weak It can be removed easily when not required

(3) In cases of complete loss of flexion the patient's work may necessitate a constant change of power of spring This small splint, worn on the outside of the clothes, may prove more useful when at work than the more elaborate type worn under the clothes as it is not so easy to keep changing the spring resistance.

Materials

Strong tanned hide, 2 D rings $\frac{3}{4}$ inch, 4 buckles, 4 straps $15 \times \frac{3}{4}$ inches, rivets, chiropody felt $\frac{1}{8}$ inch

Measurements required

The arm should be measured around the middle third of humerus and around the junction of the middle and lower thirds of the forearm

Construction

Cut two pieces of hide the size of the arm, by 4 inches wide Along the edges of both these pieces fix the straps in the method already described Fit the forearm piece and trim the edges to the graded measurement over this area to obtain a good fit and prevent slipping

The opening of both cuffs will be positioned over the lateral aspect of the arm

The D rings

With a pair of pliers very slightly bend in one of the arms of each D ring, enough to allow a smooth entry of the loop of the springs

Fixing the D rings—Cut two strips of hide $1 \times \frac{3}{4}$ inch, pass each of these through the D ring and secure the ring to the cuff

Securing the D ring to the cuff—The strip of leather is riveted to the cuff with two rivets each side of the ring in a medial to lateral direction so that the D ring is in a perpendicular position and the *rounded* side within the fixing strap The upper D ring lies over the biceps and the lower one on the cuff with the hand in mid position Complete the splint by securing the lining

Progress

Careful supervision should be given to see that the spring keeps pace with the increasing power of the triceps The patient should have muscle power, at least

Grade 3, before applying the splint for resistance, otherwise he will use trick movements instead of using the resistance If power is very weak a spring long enough to resist the outer range should be used at the start of treatment

Duralumin Hinges for Use with Lively Splints

General description

The hinges are made of the lightest possible metal They consist of two rods which are flat on one side and rounded on the other (making for extra lightness) They are joined together by three different types of hinge joints The rounded side of the rods face away from the arm

On each rod of three of the hinges a metal hook is attached by rivets, the hooks facing away from the hinge joint (*see* Figs 81, 82, and 83)

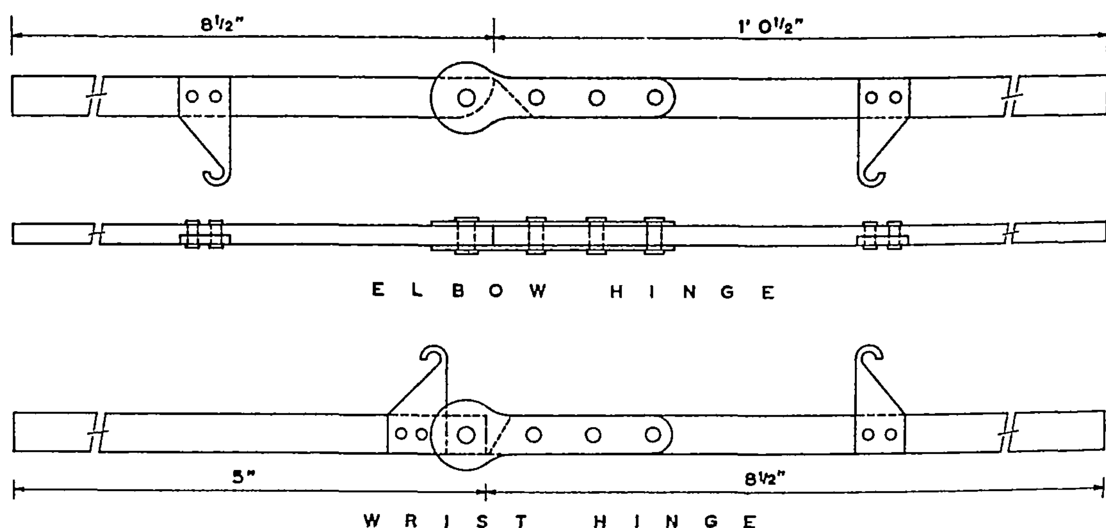


Fig 81

Indications

Elbow flexion hinge

To assist elbow flexion by spring action

Elbow extension hinge

To assist elbow extension in cases where gravity does not provide enough assistance

Wrist extension hinge

To supplement wrist extension

Elbow flexion stop

To allow fixed elbow flexion at several angles when the elbow is flail

Measurements

Elbow flexion hinge

One arm is termed the upper arm rod and the second arm is termed the forearm rod

Upper arm rod

This is 10 inches in length from the centre of the hinge The hook is riveted 7 inches from the centre of the hinge

Forearm hinge

This is 8 inches in length from the centre of the hinge and the hook is riveted $2\frac{1}{4}$ inches from the centre of the hinge

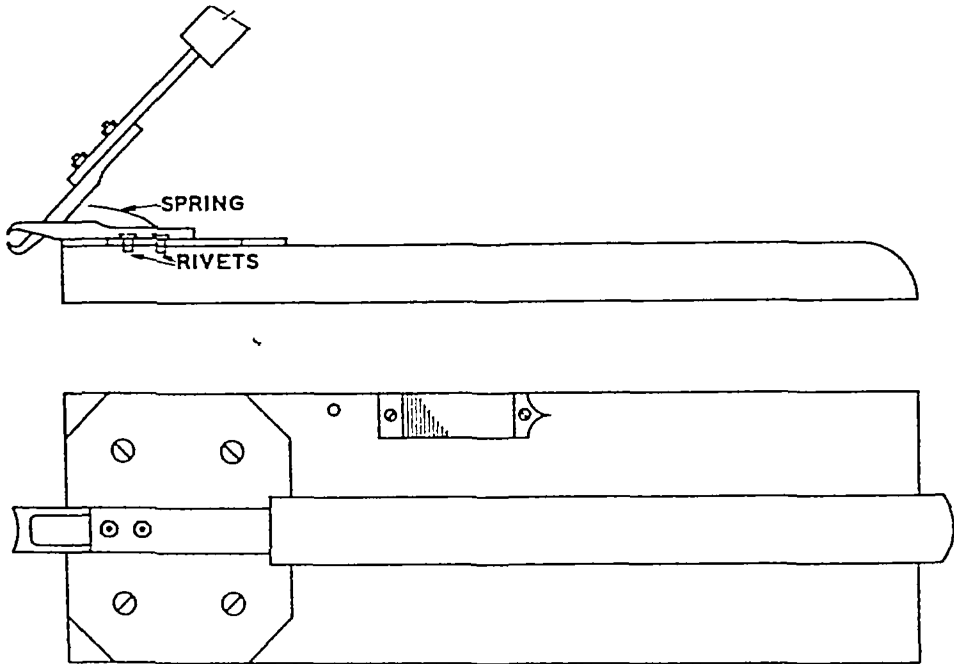


FIG 82

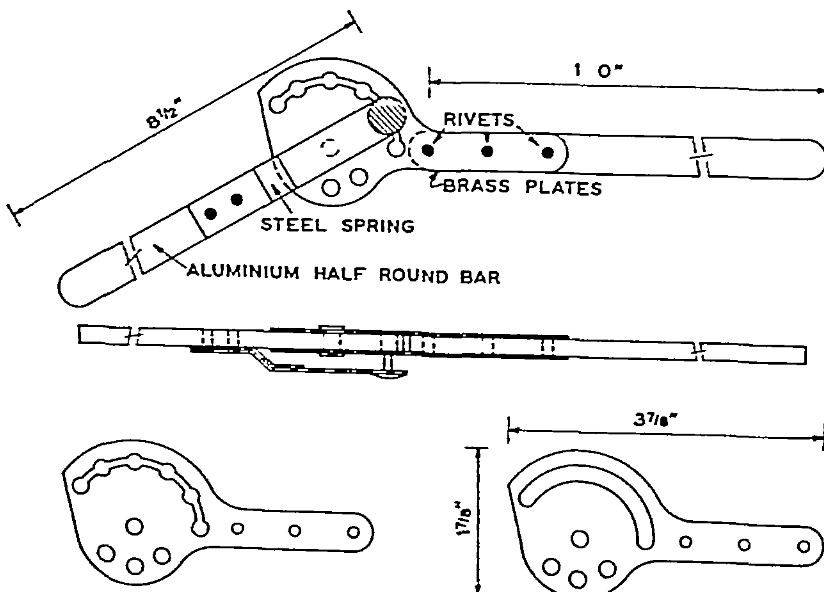


FIG 83.

Grade 3, before applying the splint for resistance, otherwise he will use trick movements instead of using the resistance If power is very weak a spring long enough to resist the outer range should be used at the start of treatment

Duralumin Hinges for Use with Lively Splints

General description

The hinges are made of the lightest possible metal They consist of two rods which are flat on one side and rounded on the other (making for extra lightness) They are joined together by three different types of hinge joints The rounded side of the rods face away from the arm

On each rod of three of the hinges a metal hook is attached by rivets, the hooks facing away from the hinge joint (*see* Figs 81, 82, and 83)

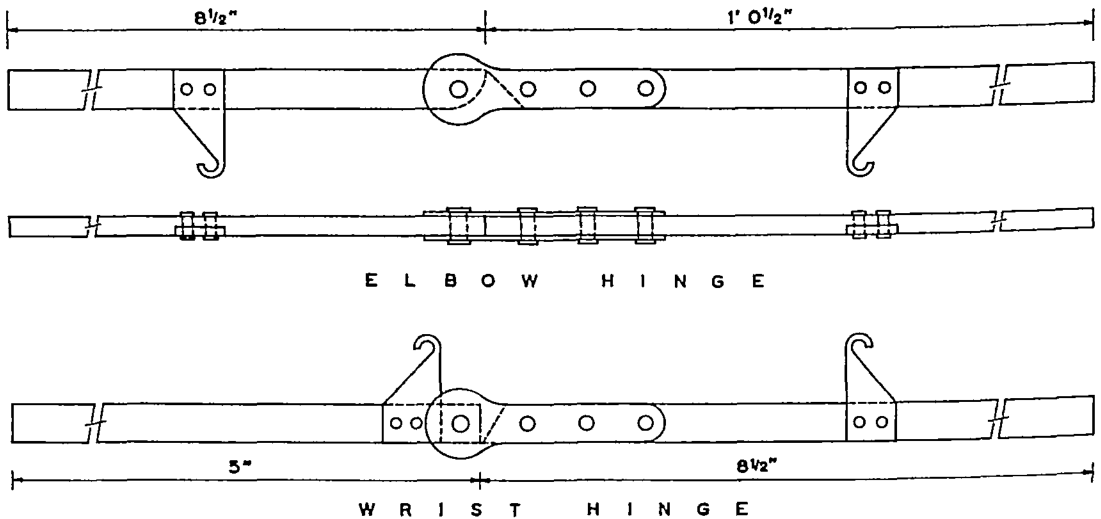


Fig 81

Indications

Elbow flexion hinge

To assist elbow flexion by spring action

Elbow extension hinge

To assist elbow extension in cases where gravity does not provide enough assistance

Wrist extension hinge

To supplement wrist extension

Elbow flexion stop

To allow fixed elbow flexion at several angles when the elbow is flail

Measurements

Elbow flexion hinge

One arm is termed the upper arm rod and the second arm is termed the forearm rod

CHAPTER 8

TECHNIQUES OF TREATMENT

PHYSIOTHERAPY

THIS section deals with some specific points concerning the techniques of treatment that are considered to be of particular importance

The rationale of treatment and conventional techniques are not discussed when these do not differ from normal practice

Oil massage

Olive oil is used and should be heated in a warm bath The physiotherapist should test the temperature with her own hand before applying to the patient When the skin is dry and thin, light pressure only is used in the form of effleurage

Particular attention is paid to massaging around the nail beds where trophic ulcers are very liable to form

For thick skins and deep adherence of soft tissues, zinc oxide is the better agent Frictions are given, both transverse and in a circular direction They should be alternated, the physiotherapist using increasing pressure with her thumbs The treatment is finished by the physiotherapist stretching the skin between her thumbs, both longitudinally and transversely When scars are really thick and adherent, a heavy cream consisting of one part Vaseline to three parts lanoline is most effective When adherent tendons are being loosened, the patient is asked to contract the muscle so that the tendon can be seen easily Provided that sufficient time has elapsed since suture or grafting, treatment should be finished with a slow stretch of the tendon in a longitudinal direction

Indications

(1) Preparatory to passive movement oil massage enables the patient to get the feel of the physiotherapist's hands For this purpose a few minutes only of light effleurage and stroking are indicated

(2) Effleurage in a centripetal direction with the hand in elevation is very effective in reducing oedema preparatory to passive and active exercise

(3) Oil massage is useful in reducing adherence of soft tissues—both tendons and fascia, as in Dupuytren's contracture, thick scars, results of burns and fibrosis following oedema

(4) Oil massage improves the circulation when passive movements and active exercises are not possible or are likely to be ineffective as, for example, when joints are extremely stiff

(5) The viability of the skin is restored and its general condition is improved by oil massage particularly in peripheral nerve injuries and in all conditions where there has been sensory loss

Stretches

Indications

The following are indications for stretch treatment

(1) For soft tissue and tendon adherence as in multiple injuries of the wrist,

Movement

The hinge is blocked to 180 degrees on opening out and to 45 degrees on closing Both hooks are on the closing side of the appliance and on the anterior aspect

Elbow extension hinge

The measurements for this hinge are basically the same as for the flexion hinge with the following differences The hooks are riveted on the posterior aspect of the two arms instead of the anterior aspect The forearm rod hook is 6 inches from the centre of the hinge The hooks still face away from the hinge joint

The spring does not cross the joint but is attached to the upper arm rod only and jointed to the lower hook by double 40 lb nylon thread which passes over the hinge in which a groove has been made to the forearm hook

Wrist extension hinge

One arm is termed the forearm rod and the second the hand rod

Forearm rod

This is 8 inches long and the hook is riveted 6 inches from the centre of the hinge

Hand rod

This is 4½ inches long The hook faces away from the hinge but it is incorporated in the circle of the hinge itself

Movement

The range of the hinge is 120 degrees on extension and 30 degrees on flexion It is not expected that the hand should be held at an angle of 120 degrees, but if the hand is held in this position while the spring is attached, the weight of the hand will help to overcome the initial inertia of the spring

Elbow flexion stop

The measurement for this hinge is the same as for the flexion hinge, but there are no hooks attached

The hinge

The hinge consists of a shaped brass plate at the junction of the elbow A spring stop is fitted to the inside plate which rotates round the top plate when pressed down, and slips into a slot cut for it when released

Measurements

The plates are made of brass to overcome the problem of rusting and constant friction Although it adds weight to the hinge it has been found that other metals are not so satisfactory

Conclusion

It may be asked why straps should not be used instead of the full cuffs, as these obviously make the splints less cumbersome The reason is that each of the hinges carries the weight of the forearm as well as any muscle resistance If two straps to each rod are used, it means that all the resistance is concentrated at these two spots only. With the fuller cuffs, the resistance is distributed evenly over the whole area, the splint is more comfortable and there is less risk of circulatory disturbance

REFERENCE

SHARRARD, W J W (1955) "The Distribution of the Permanent Paralysis in the Lower Limb in Poliomyelitis" *J Bone Jt Surg*, 37B, 540

movements are started in the distal joints and work up to the proximal joints The movement of the small joints is less painful than of the larger joints, it is better, therefore, to hold the patient's confidence, to start with the small joints Movements are given in each direction, increasing in range a little each time The adjacent joints must always be supported throughout A little traction is applied at the end of each passive movement When the maximum range is reached, the physiotherapist should apply slight pressure to make sure that this is indeed the full range obtainable As with stretches, it is advisable to examine the normal range which varies from one patient to another

Wax baths

Indications

Wax baths are of value in the following

(1) As a means of warming the hand prior to exercise, passive movements or stretches

(2) To improve the skin condition

(3) To improve the circulation, particularly in Sudeck's atrophy

(4) When the patient's hand is so cold that he cannot use it, a wax bath is particularly useful before occupational therapy

Contra-indications

Wax baths should not be employed in any of the following conditions

(1) When there is more than a slight break in the skin

(2) If blisters or burns are present

(3) In any type of skin graft No form of heat should be used after skin grafting as there is a definite risk of killing the graft

(4) Any form of infection in the hand

(5) Where there is a poor circulation and incipient gangrene

In some cases it is wise to recommend the patient to give himself a wax bath at home if his hand is very cold or stiff in the mornings It is particularly useful for patients with rheumatoid arthritis

All patients should be carefully instructed in the correct technique, particular care being taken to ensure that the wax is always heated in a water bath

In general, the effects of heat are the relief of pain, the facilitation of movement, and increase in circulation

Wax is the method of choice whenever possible in the hand, as uniform heating occurs in all the small joints When wax baths are contra-indicated infra-red or radiant heat are used When there is an open wound it should be shielded carefully before exposure to any form of heat

Technique

The wax bath is usually given at a temperature of 110°F, or slightly lower at 100°F if there are any trophic changes It is essential to inspect the skin to see if there are any open wounds A finger-stall can be worn if there is only a tiny wound If a wound of any size is present saline solution soaks should be used instead of a wax bath Hairs and nails should be trimmed before immersion The hand is immersed in the wax bath and removed after a few seconds, when the shine has left the wax the hand is re-immersed and the process continued until ¼ inch

Dupuytren's contractures and tendon adherence following suture or grafting at any joint along its course

(2) Following capsular contraction, when joint movement is reduced, as may occur in arthritis or after intra-articular fracture

(3) When there has been over-correction of a deformity in plaster

(4) When there has been tightening of the fascia in paralysis, as in poliomyelitis and hemiplegia

Technique

A stretch is a long-continued passive movement at the end of the range, used to mobilize soft tissues

Before using passive stretches the patient should be warned that the treatment is bound to be uncomfortable, and the importance and nature of the treatment should be explained so that he will be ready to co-operate He should be shown, on the unaffected hand, the normal range of movement of the particular joints about to be stretched This is important because many patients do not realize the extent of the range of movement in the proximal interphalangeal joint and terminal interphalangeal joints, and they might thus be led to believe that the physiotherapist is overdoing the treatment The hand should be warmed before treatment to relax any spasm It is immaterial what method of heat is used provided it is appropriate to the particular circumstances The passive and active range should next be examined carefully to locate where the tightness occurs Treatment must be progressive, working up slowly to a prolonged stretch The treatment lasts approximately 10 minutes and must always be followed by splinting, usually in a light plaster splint as described later so that the maximum correction obtained can be kept until the next session

When there is much soft tissue adherence stretches should be given 4 times a day The antagonists must be made to contract to their maximum extent so that full relaxation is possible Throughout the stretches the adjacent joints must be well supported At the final extreme of the stretch, a certain amount of traction is applied in order to mobilize the adherent structures

Passive movements

Indications

Passive movements are indicated in the following

(1) Whenever the patient cannot actively move the joint due to muscle paralysis

(2) To prevent capsular contraction in a progressive deformity

(3) To prevent permanent effects of spasm

(4) To improve the circulation, both in paralysis and in osteodystrophy

(5) To prevent fascial tightening in poliomyelitis and Dupuytren's contracture

These are usually combined with passive stretches

Technique

Passive movements should always be given after some form of heat and oil massage The patient must always be warned that the treatment may be uncomfortable, and the range of movement in the unaffected hand should be demonstrated to him Once the patient is relaxed the range of movement is progressively increased to a maximum at the end of the session It is advisable to obtain good contraction of the antagonist in order to obtain full relaxation The passive

habit of giving such treatment is so widely used that it would require some convincing proof of its uselessness before it could be abandoned There is no doubt from the work done on animals that electrical stimulation is effective in preventing, to some extent, atrophy of muscle and delaying its onset The relevance of these results to the problem in man does not necessarily follow A Medical Research Council Committee is now working on this problem Until such time as more definite proof of its efficacy, or otherwise, is to hand, it would be wise to confine any form of electrical stimulation to denervated muscle when recovery in a reasonable time is anticipated, and when such treatment is practical Consequently, there would seem to be a place for the provision of small stimulators which patients could use at home

Stimulation certainly keeps the tendons moving in their sheaths and prevents adherence during the stage of paralysis

Contra-indications

Electrotherapy is of no value in the following conditions

(1) Any anterior horn cell lesion, because the damage is permanent and irreversible, electrical stimulation is thus of no value in poliomyelitis

(2) There is no need for electrical stimulation in neurapraxia

(3) It is of no value unless the patient can have the treatment at least 5 times a week It should be stressed that irrespective of the nature of the lesion, or whether there is recovery or not, the correct form of stimulation is that found to be most comfortable for the patient and the most effective in producing a good contraction

Choice of stimulation

The best type of current to use for stimulating denervated muscle therapeutically is one that takes time to reach its maximum—a so-called progressive current

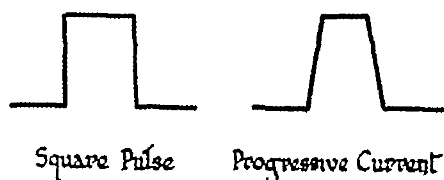


FIG 84—*Diagram of square pulse and progressive current waveforms used in therapeutic electrical stimulation*

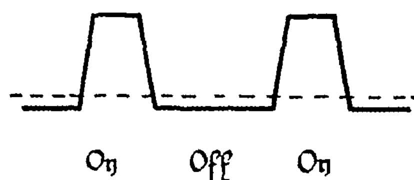


FIG 85—*Diagram of a balanced pulse output During the off period of the current a small reverse charge is passed to offset ionization during stimulation*

This has two advantages over the conventional square pulse wave First, it is more comfortable as the shock is less abrupt and, secondly, it has the property of selectively stimulating denervated muscle without stimulating normally innervated muscle, thus being most useful in treating a partially denervated muscle

The normal muscle has the power of accommodating to slowly rising currents so that it does not contract until a fairly high output is given, much higher than with a square pulse The denervated muscle does not possess this property but contracts at a low output, particularly as its rheobase is often lower than normal (Fig 84)

It is advisable to use a balanced pulse stimulator to minimize erythematous

thickness is obtained The hand is then covered with paper and sufficient cotton-wool with lint covering to retain the heat If the hand is oedematous it is elevated and movements encouraged in the wax After 15–20 minutes the wax is removed and treatment commenced Although the wax retains heat for a long time, patients must still wear a glove when leaving the department to go out of doors

Dangers of heat

There is danger in applying heat in the following conditions

(1) Whenever there is an area of anaesthetic skin, as in peripheral nerve lesions or syringomyelia The use of heat is not completely ruled out in such conditions but extreme care must be taken in its application

(2) When the circulation is poor, as in vascular diseases such as Raynaud's phenomenon, Volkmann's ischaemic contracture, Buerger's disease, and so on

(3) It is wise never to apply heat after skin grafts, this applies also to flaps

(4) Tuberculous conditions of the skin, tendons or joints

(5) Any form of malignancy

(6) After thin dissections, as, for example, after excision of Dupuytren's contractures

Manipulations

Manipulations are always contra-indicated in the hand Very occasionally a stiff wrist may require manipulation under anaesthetic, but *in no circumstances are manipulations given to metacarpo-phalangeal or interphalangeal joints* Manipulations given for stiffness of joints due to intra-articular damage invariably result in less movement afterwards

Manipulations for soft tissue adherence always produce more fibrosis When soft tissue contracture is present, massage combined with slow continued stretches is the treatment of choice

Mackenzie, W C, stated " Given the pressure, however slight, but continuous and concentrated, and contractures even of the extreme and apparently hopeless type will be found to yield without the aid of what should always be the last and not the first resort—the knife "

Electrical stimulation

Indications for electrical stimulation of muscle

When the muscle is denervated, electrical stimulation is advisable whenever there is a reasonable prospect of the muscle being re-innervated before the onset of fibrosis The muscle is likely to become fibrotic however well treated, roughly 2 years after denervation, if not re-innervated There is some controversy as to whether evidence for its value is sufficient to warrant the regular stimulation of denervated muscle The vast majority of experimental work in this field has been carried out on animals

The published work of any significance on electrical stimulation in man is confined to two main papers, those by Doupe, Barnes and Kerr (1943) and Jackson (1945) In neither of these contributions, however, was the work output of the muscle measured before and after denervation, nor were control measurements performed There is, however, a strong clinical impression among workers in this field that electrical stimulation does delay the onset of atrophy, and the

Light power

Cane work—This is good in the early stages of injury to start mobilization and to restore the confidence of the patient in using the injured hand The emphasis is on the dynamic tripod The movements are as follows

(1) Metacarpo-phalangeal flexion and interphalangeal extension

(2) Metacarpo-phalangeal flexion with outer range of the long flexors of the 2 fingers and the thumb

(3) Pronation and light wrist movement

The activity is dynamic, rhythmical and repetitive, and extreme positions are avoided It can be comfortably carried out in slings if oedema is present and the patient is required to work in some degree of elevation

Because of the complementary activity needed with both hands, it is extremely useful for training of co-ordination of the hands for patients suffering from disseminated sclerosis and other upper motor neurone lesions

It can be carried out from right to left, or from left to right, according to which hand needs the controlling movement According to the articles chosen, progression to moderately strong work can be quickly achieved

Woven tufted rugs—An almost complete dynamic tripod function, it has two dominating movements

(1) Metacarpo-phalangeal flexion and interphalangeal extension

(2) Metacarpo-phalangeal flexion with middle range of long flexors

The resistance is little more than 1½ lb

It is not suitable if quick progression is required, but the movement is bilateral and can be used in upper motor neurone lesions, poliomyelitis, and median nerve lesions

Wireless construction—This involves a more diffuse use of the hands and is dependent on a patient being right- or left-handed for specific treatment

Most of the tools need the use of the Scribes' tripod Muscle work is light, but particularly useful for re-education in fine movements for patients used to coarse heavy work who, through disability, need retraining

Other activities which give the Scribes' type of function of a light nature include marquetry, electrical assembly work, type-setting, balsa wood carving, lino-cutting, tapestry work and painting

Intermediate power

Pottery—A valuable craft for the intermediate stage after injury The preparation of the clay uses every kind of movement of the hand, particularly interphalangeal joint extension, finger flexion, strong thumb flexion, and has the advantage of progressing to the finer movements of the hands (*see* Table I)

Other crafts in the intermediate power range of Scribes' function

These include wood carving, metal filing, tanned hide leather work, willow basketry, screwdriving, assembly work, block printing

Heavier work progression involving the same movements

Veneering, french polishing, rebating, painting and decorating, wood cleaning, tin bending, metal cutting and shaping for garden tools are among the heavier types of work

reactions when the patient is having treatment daily for many weeks or months In this type of stimulator a low current of opposite sign is passed in the " off periods " (when the muscle is not being stimulated) not sufficient to cause sensory or motor stimulation, but enough to reverse ionization effects produced during the " on phase " of the current (Fig 85)

The following are certain circumstances where electrical stimulation is valuable when the muscle is innervated

(1) To encourage early movement after tendon repair when the patient cannot initiate movement himself

(2) When there is gross inhibition of muscle action due to pain or some other cause which prevents the patient contracting the muscle himself Examples are Sudeck's atrophy and painful amputation stumps

(3) To improve the circulation and relieve oedema in patients with gross oedema and very weak muscle

In these conditions a short duration impulse is used of 1 or 0 3 milliseconds, depending on which the patient finds the most comfortable The patient should assist the movement with the electrical current, every 5 minutes the current should be reduced and the patient asked to perform the exercises unaided

In the early stages of recovery of lower motor neurone lesions, muscles tire easily when used voluntarily and it is useful to add electrical stimulation when the patient can no longer perform the movement himself The type of current used may be long or short depending entirely on which is the most comfortable for the patient and the most effective therapeutically The best type of therapeutic stimulator is thus one that offers a wide range of pulse durations, the most comfortable and effective one can then be chosen This may vary from day to day

TECHNIQUES OF OCCUPATIONAL THERAPY

Work analysis

An analysis of the muscle action involved in different crafts is valuable in assessing activities to improve function, and to evaluate a patient's work potential

It is not intended to discuss the most suitable techniques to be used in any one department, as this must bear relation to whether the area is rural or industrial, the type of hospital or rehabilitation centre, the average age of the patients, the facilities available and the number of staff

It is with this in mind that some attempt has been made to classify the more frequently used working positions of the hand into patterns which can easily be recognized for activity, assessment and for aids in disability

Scribes' position activities

In the following conditions it is required to give special emphasis to the muscles of the thumb, the index and middle fingers and the intrinsic muscles

(1) Ulnar and median nerve lesions, Bennett's fracture, fractured phalanges, skin grafts, flexor and extensor tendon lesions (sutures and grafts)

(2) Re-education of the thumb, with the ring and little fingers in the dynamic tripod, in amputation of the index and middle fingers, or similar disabilities

(3) Re-education in upper motor neurone lesions and poliomyelitis affecting the hands

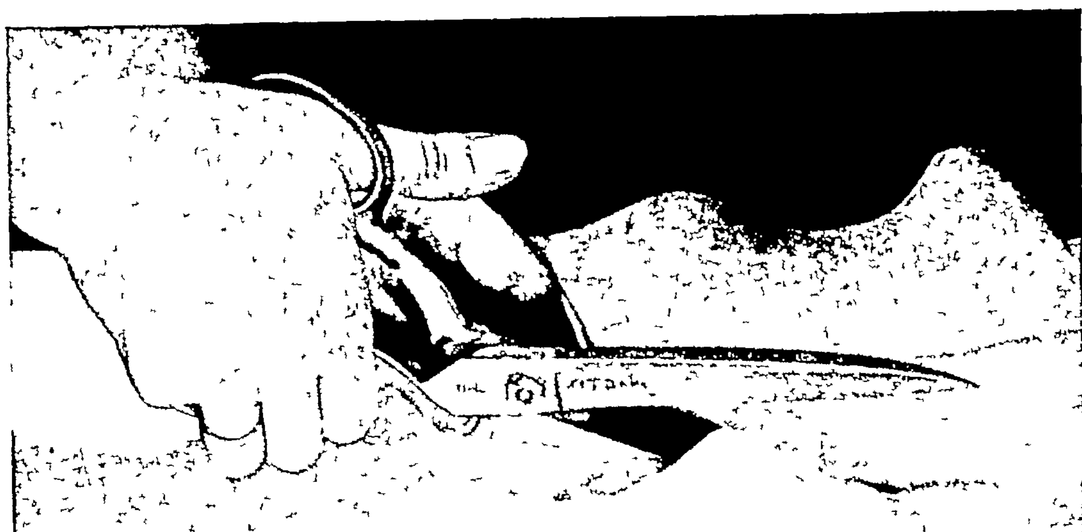


FIG 86 —*Tailor's scissors used for encouraging extension of the thumb*

and intrinsics, mobilization of stiff joints, re-education after amputation, and mobilization of joints after skin grafts

Carpentry

Chisel—The main value of using this tool lies in the fact that in making a tenon and mortise joint, the chisel is used with the left hand in a right-handed person In this particular joint the tool lies diagonally across the palm in an ulnar direction, whilst the hand assumes ulnar deviation and pronation There is a particularly strong contraction of abductor minimi digiti in the end movement Control needed in steadying the tool lays particular emphasis on the intrinsics Constant measuring for depth ensures that the grasp is released at frequent intervals

When used by the initiating hand across the wood it is used in full grasp with the thumb lying along the handle

The part played by the intrinsics in strong grasp is a valuable method of increasing their power to enable them to perform their finer functions both in nerve injuries and poliomyelitis

Mallet —This tool is found particularly difficult to control efficiently by patients suffering from an ulnar nerve lesion before any recovery has taken place

Due to the weight at the end of the lever particular power is needed by the ring and little fingers in putting on the brake at the end of a movement directed by the thumb, the index and middle fingers Although the prime mover is the long flexor, there is a strong control of this action by the abductor minimi digiti and the adductor pollicis in the normal movement This is most noticeable when a small arc of movement is being used, with delicate control of the chisel

The mallet is a powerful builder of the long flexors of the forearm, especially if extra weight is added by drilling a few holes in the head, into which shot is sealed

There is emphasis on flexion of the middle finger which appears to act as balance between direction and control of the other fingers—a useful point to note when treating a tendon graft to this finger

TABLE I

DOMINATING MOVEMENTS IN POTTERY

Clay wedging	Middle third range of long flexors Approximately 5–12 lb resistance
Hand Bi-lateral	A strong synergistic action of intrinsics Middle third range of long flexors of the thumb, and extensor pollicis longus and brevis action as both prime mover and antagonist Strong thumb rotation and hypothenar action
Throwing hand Bi-lateral	Wrist extension, metacarpo-phalangeal outer range flexion, interphalangeal control, mild long flexor action Thumb rotation, intrinsic action and control
Coil and slab	Metacarpo-phalangeal flexion and extension, strong intrinsic action
Precautions	The skin must be fully healed and fairly strong, the temperature of the room should be warm and warm water used

Thumb extension

Re-education of thumb extension is required in radial nerve palsies, suture of extensor pollicis longus or brevis, fractures involving the thumb, and adduction contractures

Effect of radial nerve palsy on full function of abduction of the thumb

When the extensors of the thumb are paralysed a severe limitation is imposed on the range of movement of the thumb, particularly in palmar abduction This point is emphasized to clarify choice of some of the functions for building up thumb extension

Tailor's scissors—These have a large loop for the 4 fingers and one loop for the thumb The cutting action is by extending the thumb combined with partial flexion and extension of the metacarpo-phalangeal joints (Fig 86)

Piano playing—For patients familiar with the art, piano playing will use the full span of the hand in the flattened triangle

Draughtsmanship—This uses the flattened triangle position of the hands with intermediate to full span

Forceps no resistance—The extensor pollicis longus is particularly involved in the use of forceps

It is possible to arrange competitive games between two patients using forceps They can also be used for setting stones into jewellery They are most useful for re-education in median and ulnar nerve lesions

Typing—This is useful for those familiar with the function Spacing is performed by the long abductor and extensors of the thumb (prime mover action)

Bricklaying—Prime mover and antagonist A wide abduction range

Jack planing—Prime mover and antagonist Middle range of abduction span

Flat rug weaving—With a very wide shuttle A wide radial abduction span

Tree and rose pruning with secateurs, and leather work punches—Both give a useful extensor pollicis brevis action (prime mover and antagonist)

Labourer's position

Activities in this position are useful for encouraging palmar grasp, and stronger activity of the long flexors of the forearm, building up power of the wrist extensors

(3) (*a*) Function tests
(*b*) Work tolerance tests
(*c*) Personality tests

Reports should be clear, concise, and typewritten Each new point should be headed and underlined, in order that the doctor can pick out at a glance what he most wishes to know Where possible, information should be tabulated

Consideration should be given as to whether the doctor has been able to keep in constant close touch with the patient, or whether the report is to a consultant who cannot follow daily progress, one will need more information than the other

The personality of the patient

(1) The ability of the patient to deal with disability and persevere with any aids which may help function

(2) Using the injury as a shelter, from loss of confidence or seeking sympathy

(3) Any abnormal mental reactions which have emerged as a result of severe injury, such as depression or hysterical reactions

The incentive to assume responsibilities

(1) Attitude towards compensation in relation to response to treatment

(2) Family obligations and the wish to resume the running of the house as independently as possible Loss of wages, continuance of studies, loss of promotion, continuance of full wages may show up disinclination for a quick return to work

The type of work to which the patient will be returning

(1) Physical ability to carry out the work

(2) The patient's will to tackle the work first before deciding on an alternative

(3) Assessment of the work involved

Power in relation to the work to be performed

A detailed analysis of muscle power in relation to function needed for daily demands, load and endurance

Work tolerance and age

(1) Whether shock or injury has precipitated senile changes making a patient unfit for his old job

(2) Ability to do a full day's work

Whether the job itself will help final rehabilitation

By analysis, will the job itself give the necessary exercise to complete full function, thereby getting a patient back to work sooner?

No residual disability

This implies a full work-out on muscle function, power, ability to perform a full day's work, and, as far as possible, tests on work as near the patient's own job as can be devised

Slight residual disability

(1) A functional (not muscle) analysis of disability

(2) Compensations, if any

(3) Aids to overcome this, when possible

(4) Residual inability to perform any function

In amputations of the ring and little fingers, control of direction has to be assumed by the middle finger, and the mallet is a useful tool in helping to build up final power

Dominating movements (*a*) Wrist radial extension and ulnar flexion, (*b*) full finger flexion and thumb flexion

Hammer—The movements are similar to the above, with more elbow flexion and mild extension, but not quite so powerful on extension

Rip saw—This gives strong flexion of all fingers and thumb, shoulder movement for initiating hand, with good grasp by the second hand employed by holding the wood being sawn

Screwdriver—This should be used dynamically by the initiating hand

Dominating movements (*a*) Flexion of the fingers and thumb, (*b*) Pronation and supination, (*c*) powerful contraction of the abductor minimi digiti

PLANNING FOR ASSESSMENT

Planning for assessment should consist of two parts

(1) Continued observation throughout treatment of all the immediate concerns of the patient's daily needs, some of which can be dealt with as they arise

(2) Final summing up of the patient's functional potential, his disabilities or limitations in relation to daily living and working ability In the event of the patient having to be retrained, any special skill or talent which may have emerged during treatment should be noted

In order to be able to make an assessment of a patient's work potential with some accuracy, it is necessary to have a knowledge of the type of work which he or she will have to tackle This does not mean that one should know how to do every job, which, of course, is quite impossible, but that some effort should be made to become familiar with local industries and activities, in order to be able to weigh up a patient's function in relation to his work, or be able to suggest a possible alternative

To a trained treatment staff it is not difficult to assess the types of movement involved, and the power and tolerance needed for certain jobs, provided that time has been allowed for a considered judgment, and discussion has been possible with foremen or managers Quite a lot can be learned from patients themselves as they pass through the hospital, which, although they may not be disabled, will build up one's own knowledge in assessing ability

A basic plan of assessment involves some of the following points before analysis of function is finally made

(1) (*a*) The personality of the patient
(*b*) The incentive to resume responsibilities
(*c*) The type of work to which the patient will be returning
(*d*) Power in relation to the work to be performed
(*e*) Work tolerance and age
(*f*) Whether the job itself will help final rehabilitation

(2) (*a*) No residual disability
(*b*) Slight residual disability
(*c*) Gross residual disability

possible to change work apparatus which will obviate this (anything from kitchen utensils to factory apparatus)? It is wise to weigh up which of these alternatives will cause the patient least inconvenience and expense

(3) Time should be allowed for the patient to try out trick actions which may often give him more independence than being strapped up in a piece of apparatus Is there any compensation which can be taught to substitute for the disablement?

(4) If apparatus is decided upon, what are the lightest, most cosmetic and simplest materials to use

(5) How can the design be made to give least self-consciousness to the patient, and in the case of children, can they be made fun to wear?

A spoon adaptation can have a series of animals' heads cut out in Perspex, given names, and inserted on the dorsal aspect of the hand

Principles of design

Assessment

Every patient presents his or her own set of problems, and it cannot be possible to have a set group of rules to deal with disablement It is, however, advisable to have a foundation of assessment whereby the problem is reduced as far as possible, and less time is spent on trial and error

The following is a suggested plan which can be amplified or altered to suit the circumstances

Questions to be answered

(1) What is the personality, temperament and age of the patient?

(2) What is the disability, the prognosis, and the plan, if any, of reconstruction?

(3) Is temporary or permanent assistance needed?

(4) Is it the hand itself which needs compensation, or is it loss of function in the upper limb reducing the efficiency of the hand, or both?

(5) What function remains, what function is lost?

(6) What is the patient's daily routine from rising, including work, self care, hobbies, recreation, and how are these affected?

(7) Will the aid have to be worn all the time or for special skills?

(8) Will it need to be waterproof?

(9) Will facilities be available for repair, alteration or renewal?

(10) What is the condition of the skin and circulation, and will they tolerate pressure and coverage?

(11) Are there any materials to which the patient is allergic?

(12) Is the disability single or bilateral?

(13) Will new skills have to be learned in re-training, and how will this affect the design?

(14) How long will the patient be available for supervision to ensure efficient working of the aid, and how long will be necessary to assess efficiency?

FUNCTIONAL ASSESSMENT AND POSSIBLE AIDS AND COMPENSATION

Amputated terminal joint of the thumb

Pinch movements entailing interphalangeal joint extension with metacarpo-phalangeal joint flexion are no longer possible

(5) Suggested adaptations for the job or running of a home

(6) Precautions in relation to disability and job, such as anaesthetic areas, flexion contractures of the fingers which might catch in the wheels of a machine, lack of power in a hand which, although capable of performing the functions required for the job itself, might constitute a danger One example is a riveter, who might have to haul himself into high positions which need balance or hand support in an emergency

Gross residual disability

(1) Ability to deal with all the functions concerned with daily routine

(2) What steps have been taken to help these problems

(3) What problems still remain, and whether there is a possible solution

(4) Possible work potential, inclinations, skills, suggestions, contacts

Functional tests

(1) These should bear relation to the work performance necessary, but should be carried out in full co-operation with the patient, as only he can know how the function feels to himself

(2) They should include muscle and joint performance, co-ordination, speed and tolerance, and most of all the patient's own confidence in his ability to perform them

(3) Discussion with the patient on all aspects of the work to be carried out, and any outside factors which might bear relation to the tests, such as nightwork, overtime, positions, and factory or workshop conditions, methods of getting to and from work, hobbies and recreations

(4) Dexterity with aids or splints, and assessment of their relative value

Work tolerance tests

Assessment of work tolerance tests should start before a report is required, to be able to judge with some accuracy whether a patient can stand up to a full day's work at the speed and power required If he cannot, some idea should be given as to the limit of his powers

Personality tests

These are sometimes necessary in a patient who has some upper motor neurone lesion with concussion, or a long drawn out illness Reactions to opposition, frustrations, noise, relations with other patients, speeding up work, and difficulties to be overcome should be noted and situations evolved to test these

HAND DISABILITIES AND THE PRINCIPLES OF POSSIBLE AIDS

It is not intended to give details of every aid which has been invented, partly because these are always best shown by photographs, but also because so much has already been written on this subject that it is felt that reference to publications would better suit this purpose

Before deciding to make an aid for a patient there are several points to consider.

(1) Is the patient willing to have the aid? If not, the time spent making it or the expense of buying it will be wasted, for he or she will just not use it when away from the department

(2) Is it necessary to make an aid to function which a patient will wear, or is it

difficult Careful assessment of the patient's work is therefore essential, in view of the fact that recovery may be expected or considerable time may have to elapse before reconstruction can be performed The choice may lie between stabilizing the thumb with a restricting splint or allowing free trick movement

In closing a strong lever, such as a brake, the " hook " stabilization of the thumb, up to which the long flexors close, is lost and the thumb has to depend on adduction and flexion which places the thumb in an increasingly weaker postural position to carry the strong pull of the flexors

Prosthesis

This should give as much assistance to the adductor as possible by maintaining the thumb in stabilized abduction, enabling the thumb flexors and adductor to work more efficiently, and retaining the hook position in the correct plane Its compensation is strong power of the flexors to the thumb

When the patient's work involves a great deal of writing, with either weak thenar muscles or none, fatigue is the dominating factor and the splint described on page 101 will be found to give considerable assistance (*see* Fig 21)

Persistent pain at carpo-metacarpal joint

Limitation of the movement in a specified range may give relief and, when appropriate, allow fuller effort to build up the power of the thenar muscles The splint for this condition is illustrated and described in Chapter 5

Loss of intrinsic function

Loss of intrinsic action results in inability of the patient to flex the metacarpo-phalangeal joints and extend the interphalangeal joints, also inefficient opposition of the fingers to the thumb

This is compensated by support over the posterior aspect of the proximal phalanges, allowing the long extensors to perform the movement Abduction of the fingers is performed by the trick movements of the long extensors, as described in Chapter 3 The splint illustrated in Fig 54 is useful

Paralysis of the long flexors of the fingers and thumb

Compensations are none, reconstruction is necessary in these cases

Prosthesis

If the patient can extend the metacarpo-phalangeal joints the splint illustrated in Fig 88 might be modified to enable the patient to carry out a function essential to his work until reconstruction is performed

The function of this prosthesis is to bring the fingers into a flexed " hooking " position which might be useful in controlling a handle Some movement of this position is allowed by metacarpo-phalangeal extension The resistance of the " hook " is dependent on the power of the springs

It is possible that better efficiency may be obtained by a full posterior polythene flexion covering, if greater resistance is needed

Points of construction—A cast of the fingers is necessary and co-operation of the dental department guarantees the quality of finished finger rings

A small silver bar lies anteriorly across each ring behind which runs nylon thread after being attached to the terminal " hood " The pads of the fingers are left exposed so as to impair sensation as little as possible If the thenar muscles are affected the splint illustrated in Fig 21 can be incorporated

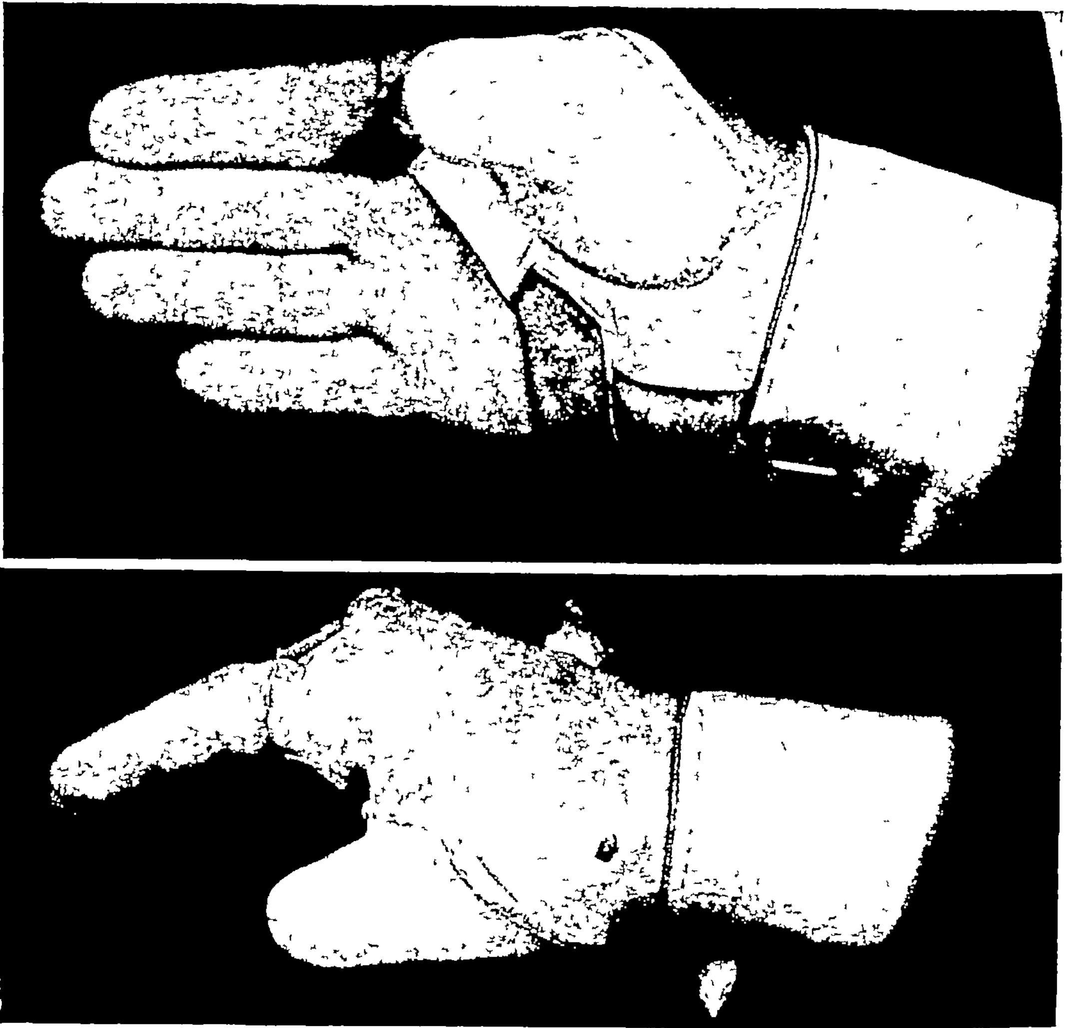


FIG 87 —*Thumb prosthesis The leather is moulded with the index finger in full flexion at the metacarpo-phalangeal joints*

Prosthesis

An acrylic thumb tip sliding over the proximal phalanx has the disadvantage of having no sensation Its compensations are education of rotation and opposition of fifth finger Education is mentioned advisedly, as over a period of years it has been observed how few people really use the full abduction and opposition of the fifth finger Full powerful education of this movement has proved of real value to 2 patients treated for this condition, as both had to wait some time for reconstruction

Amputation of the thumb

The prosthesis used is illustrated in Fig 87 The patient for whom this was made sustained a traumatic amputation of the thumb Some difficulty was experienced because for cosmetic reasons no platform had been left and the prosthesis therefore could not be as efficient as it might have been However, the patient found he could do most things with it and used it constantly

Loss of the rotators of the thumb

The dynamic tripod action is lost, and all work using this position becomes

Whillis (personal communication) stated that no one knows as the patient does the patterns he has got, and therefore the most important point is to treat the patient and not the disease The patient is an individual with individual patterns and individual habits and it is thus pointless to have a completely stereotyped regime

Compensation for loss of supination

Compensatory movements to obtain full supination can be twofold

(1) Adduction of the humerus, at the same time extending the elbow with a short throwing movement

(2) If it is necessary to keep the elbow flexed, the patient can strongly adduct the humerus, slightly depress the shoulder and at the same time tilt the shoulder towards the affected side, the weight of the hand carrying the forearm into supination

Patients usually acquire this without being taught, but older people may find it difficult without some help

Loss of elbow flexion and supination results in the inability to raise the hand to the mouth at all, and an adapted fork or spoon will be useless unless additional aid is given to the elbow by an elbow splint In the case of severe involvement a universal jointed elbow rest is used or if depressors of the shoulder are present, overhead spring assistance If the adductors of the arm are present and the patient can flex the shoulder it is probable that an elbow splint alone will be adequate, but if fixation of the tool to the hand is necessary the angle of the adaptation to the mouth must be studied

Needs of the patient

An aid to correct lack of function may be all that is necessary, but in the event of gross dysfunction, a complete chart of the patient's daily activities will be necessary with an assessment of those which he can perform adequately and those which prove difficult or impossible These will then have to be divided into possible methods of functional compensation, alternative tools, apparatus, clothes, furniture, accommodation, and, only if absolutely necessary, gadgets

Type of tool

The term " tool " in this instance is meant to signify any article which the patient has to handle during the course of the day, from a toothbrush, screwdriver, or powder puff to driving a heavy lorry

Each tool will have to be assessed as to (*a*) whether an alternative can be found which can be adequately handled, such as a combined knife and fork instead of the two separate articles, a zip instead of buttons, a rod handle to a door instead of a globe handle, or (*b*) whether adaptations can be fixed to the tool to aid efficient use, such as enlarging handles, fixing suckers to nailbrushes and mixing basins for stabilization

Certain disabilities should be dealt with as routine Patients who are going to be one-handed for 3 weeks or over should be issued with a nailbrush with suckers for attaching to the basin

Patients with circulatory disorders of the hand should be given a woollen mitt, if they cannot supply one themselves

Patients who are going to be one-handed for 3 months or more should obtain, or be supplied with, a combined knife and fork

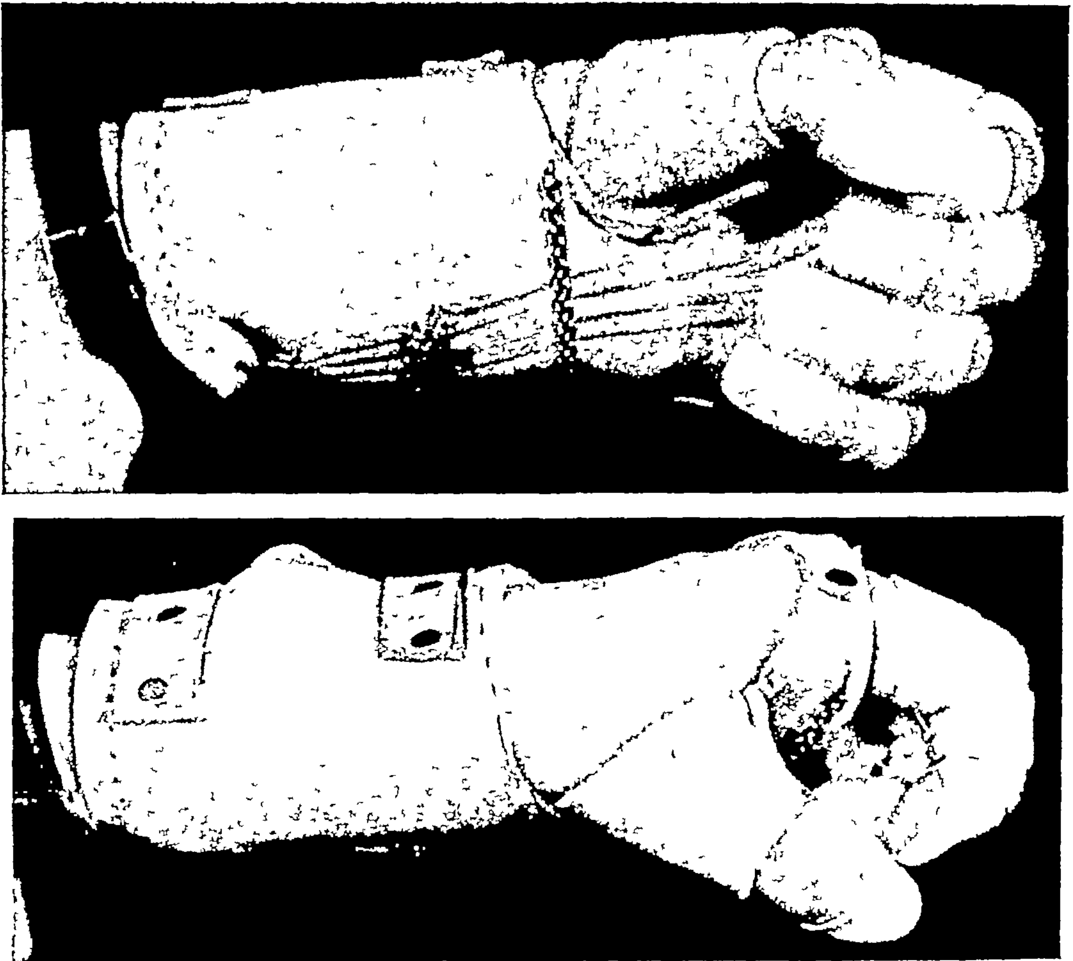


FIG 88 —*Prosthesis to give a " hook " position to a hand with paralysis of the long flexors*

ADAPTATION OF TOOLS TO THE HAND

Considerations

(*a*) Disabilities and abilities
(*b*) Needs of the patient
(*c*) Type of tool, those associated with feeding, toilet, working, hobbies

However efficiently a hand will work, it is useless if elbow flexion is lost, the hand has to be supported on a table Loss of supination impairs the ability to raise a fork to the mouth and a toothbrush to the teeth Paralysis of the intrinsics makes it difficult to fasten buttons, to write, or to hold a cup Wrist-drop results in an impaired grip, apart from the gradual deterioration of the flexors of the hand from lack of full use

It is not possible here to analyse every movement a person will use throughout the day, but a great deal of time will be saved if the patient and the therapist work together on assessing function, dysfunction and trick movements in relation to each other before the making of any aid is attempted For example, in raising a fork to the mouth the hand makes a few degrees of supination and the elbow flexes In loss of supination the patient will flex the elbow, slightly flex the shoulder and adduct the elbow towards the mid-line, slightly tilting the head



FIG 91 —*Adaptation for a weaving loom to encourage pronation and supination Gripping of the two parts of the handle together releases the pegs from the holes The grip must be maintained while the forearm movement is taking place*

A small Terry spring clip screwed to a sucker will hold a toothbrush while the paste is squeezed onto it

A large flat plastic sponge can be stitched to 4 suckers and attached to the side of the bath or basin to allow the patient to wash the good arm and hand If the hand only is out of use, a loofah glove, obtainable at most chemists, can be put over it and used to wash the other arm

Fastening shoes and tying ties with one hand usually need a little help Figs 89 and 90 illustrate two useful aids to toilet requirements

Adaptations designed to encourage a particular function

Pronation and supination

This is one of the most difficult movements to isolate without trick compensations in occupational therapy It is not enough to give a patient a disc to turn, especially as the aim is to suppress consciousness of the movement and focus the attention on the object to be achieved Apart from abduction and adduction of the shoulder, it is possible to use all the joints of the fingers and wrist to turn the disc instead of using the radio-ulnar joint

It has been found much more efficient to fix a type of handle which a patient must first grip, thus utilizing or isolating all the joints of the fingers and wrist before pronation and supination can occur Such a handle is illustrated in Fig 91 and can be fixed to a weaving loom

Two handles are constructed, one within the other Between the handpiece lie two springs As the inner handle is drawn towards the palm two pegs are withdrawn so that the round disc and the handle can be rotated If the springs are released the pegs will find their holes and the handle can no longer be turned The springs can also be varied to build up grip in addition to increasing pronation and supination

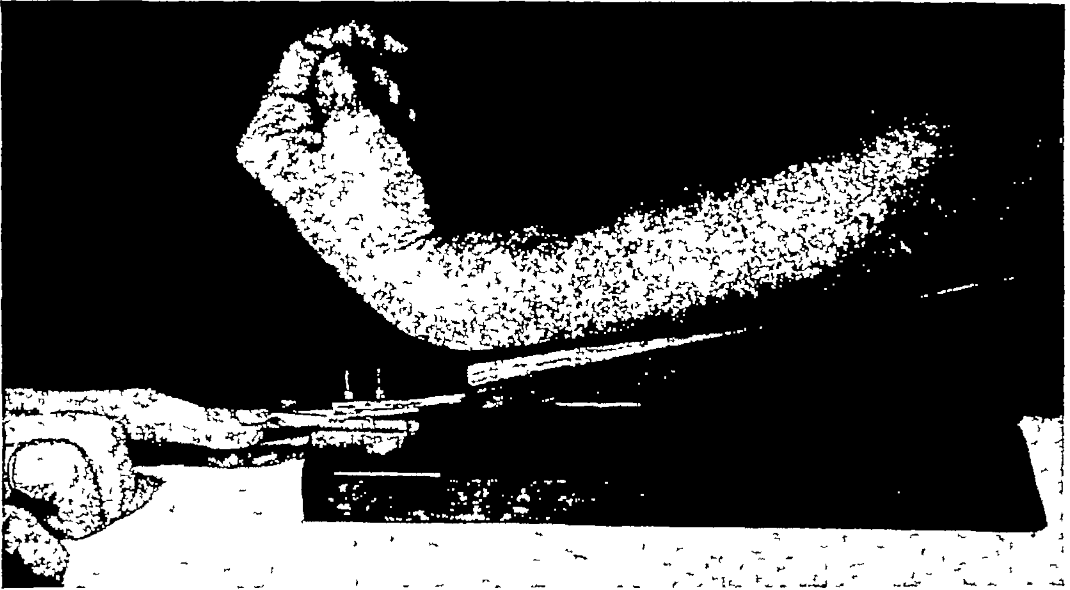


FIG 89—*Nail cutters for one-handed patients A file is attached to the platform and a hole made to take an orange stick A loop can be attached to the end of the handle for use by the foot if the other arm is not available to press down the arm lever The arm lever can be constructed at an angle if this is functionally easier for the patient*

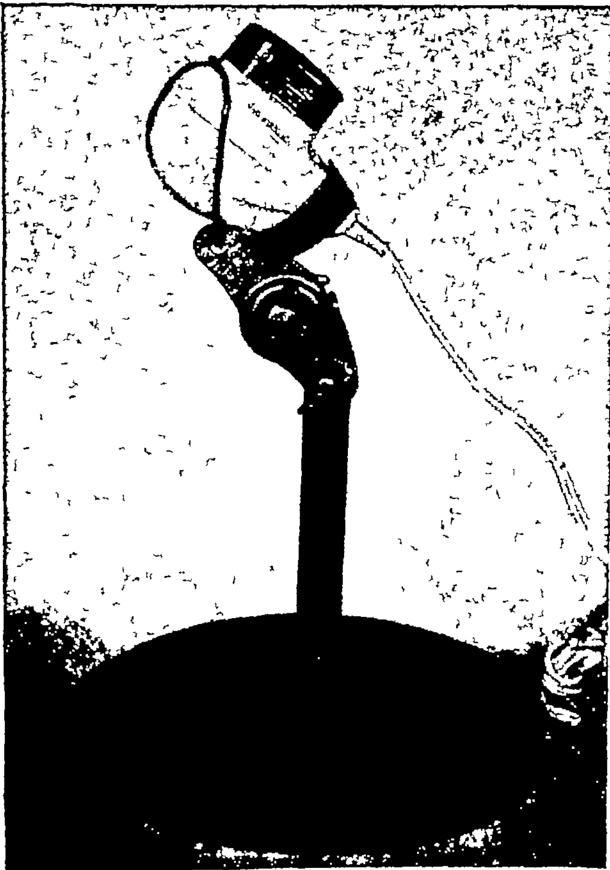


FIG 90—*Electric razor stand made for a patient with flexion of the elbow as the only active movement left in both limbs It will be noted that the joint secured by the wing nut immediately below the razor allows for positioning of the razor*

Flexor tendon grafts

Thumb, index and middle fingers	*Ring and little fingers*
Basketry	Weaving with adaptation
Stool seating	Stool seating, wide shuttle
Sandpapering	Tailor's scissors
Block printing	Punching
Weaving	Pruning with secateurs
Tufted rugs	Wood carving with mallet
Flat rug weaving	Drilling
Carpentry	Potter's wheel
Veneering	Printing
Cross-cut sawing	Carpentry
Cement work	Cross-cut sawing
Metal bending	Cement work
Pipe bending	Pipe bending

Peripheral nerve lesions

Median	*Ulnar*
Basketry	Weaving with flat round disc adaptation
Meccano	Coil pottery
Tufted rug	Potter's wheel
Leather work	Finger painting
Netting	Puppetry
Tapestry	Rule drawing
Marquetry	Block printing
Type-setting	Cat's-cradle
Jewellery	Papier mâché
Wireless assembly	Book binding
Painting and drawing	Piano playing
Modelling	Violin playing
Papier mâché	Typing
Darts	Flute playing
Peggotty	Draughts with large pucks
Halma	Laundry folding
Draughts	Veneering
Put and take	
Inlay weaving	
Tapestry weaving	
Wire work	
Filing	
Bead stringing	
Lino cutting	

For mobilization of interphalangeal joints	*To encourage thumb flexion*
Jack plane	Syphon paint spraying
Brick building	Blow football
Large disc adaptation to weaving	Punching
Brace and bit	Tin shears
Hand drill	Pliers
Lathe tools	Pincers
Tailor's scissors	Hand drill
Netting	Basketry
Knotting	Stool seating
Filing	Hooked rug
Sandpapering	Tufted rug
French polishing	Tablet weaving
Furniture painting	Gardening secateurs, trowel, rake, hoe
Upholstering	

Wrist flexion and extension

It will be remembered that the wrist is less affected by tendon pull when used in the mid-position for flexion and extension When already affected by trauma it is obviously wiser to try to obtain maximum movement uninhibited by tendon pull

The "Feps" adaptation can be attached to the side of a table so that the cylinder end is vertical, but an extra pulley will be necessary to carry the cord attached to the loom

Wrist extension, metacarpo-phalangeal and thumb extension

Flat discs are attached to the looms in the usual way These should vary in size When concentrating on wrist extension they should be the size of the palm, so that flexion of the fingers around the disc assists the movement For metacarpo-phalangeal extension the disc should be of a diameter to fit the palm plus the proximal phalanges For full extension of the thumb the disc should be the size of a hand span, but the surface in contact with the hand should be bevelled off at the perimeter to allow the tips of the fingers and the thumb to grasp and turn the disc All should be controlled by compression springs to increase resistance when necessary

Finger flexion

General—Finger flexion is particularly necessary for flexor tendon grafts in the early stage When increase in the range of the metacarpo-phalangeal joints is being encouraged, a half spherical disc can be attached to the roller If the double finger-stall is being used, the other finger will bring the affected one alongside and help to encourage the movement When it is found that the affected finger is almost within range, the stall is discarded until the movement can be carried out efficiently A smaller sphere is then used and, if weaving continues, a small flat disc should be substituted so that the finger can curl round it

Fourth and fifth finger activity—The aim is to encourage wrist flexion in an ulnar direction This will bring the emphasis of finger flexion on to the fourth and fifth fingers

A rod is attached to the holder, the end of which is bent to approximately 145 degrees The hand grasps the bent piece and the greater the resistance the rod gives, the greater will be the effort which has to be made by the fourth and fifth fingers

TABLE II

ACTIVITIES USED IN SPECIFIC CONDITIONS

Radial nerve lesions (and lesions of the extensor tendons) full grip	
Sandpapering with adapted blocks	Wood carving
Cat's-cradle	Stool seating
Weaving with large flat disc	Carpentry
Catching balloons	Pipe-bending
Block printing	Metal hammering
Rug weaving with wide shuttle	Lathe work
Paperhanging	Printing
Bricklaying	Gardening
Potter's wheel	Cross-cut sawing
Glove puppets	Cement work
Flip football	Drilling
Tailor's scissors	Table tennis
	Tennis
	Adaptations to weaving

Halma
Ludo
Snakes and ladders
Chess
Peggotty
Mah jong

Games which can be used and adapted for particular movements and positioning of the hand and arm

Draughts
Pelmanism (full size cards)
Card building
Chinese chequers
Billiards
Table tennis
Darts
Peggotty

Games useful for building up tolerance and stimulating reflex response

Blow football
Table tennis
Flip football
Flower pot and marbles

Games which demand an advanced mental picture of movement patterns

Draughts
Chess
Peggotty
Halma
Pelmanism
Billiards
Spillikins
Darts

Draughts

Draughts is still one of the more popular games among the male patients Its use encourages the following movements

Finger and thumb movements
Power of grip
Intrinsic hand re-education
Wrist pronation
Elbow extension
Shoulder flexion and one-third abduction
Functional pattern planning
Transverse movements
Adaptable to shoulder elevation

The following adaptations fulfil the above functions

Boards should be of at least 3 different sizes normal, 2 feet square, and 3 feet square The size of the pucks should range from normal up to 5 inches in diameter, the weight, from light up to as heavy as possible, the shape, flat round discs Tall thin cones, over which a ring can be dropped for the king, are particularly useful for re-education of the intrinsics of the fingers

The board can be elevated on a stand which is adjustable in height Hooks are fixed to each square and weights are used as pucks to improve shoulder elevation and elbow extension

Competitive blow football

The patients squeeze the rubber bulb of a syringe, thus blowing out air which propels a ping-pong ball along a table A penalty is awarded against a player who touches the ball with the end of the syringe

The value of this game is

To stimulate reflex response of all arm muscles
To use the outer and middle range of long flexors to the finger and thumb
To use the extensors of the wrist and metacarpo-phalangeal joints
To build up tolerance
Resistance is approximately 4 pounds

To promote co-ordination	*When emphasis on metacarpo-phalangeal joint mobilization is required*
Basketry Tufted rugs Sorting coloured beads Cord knotting Chair seating Type-setting Meccano Wireless assembly Finger painting and writing Modelling *Games—* Spillikins Draughts Card building Brick building Jigsaw Screw toy assembly	Punching Tin shears Pliers Secateurs Blow football Rip sawing Cross-cut sawing Pincers Mallet Chisel Veneering

GAMES USED IN OCCUPATIONAL THERAPY

Any disability of the hand makes a patient conscious of the individual movements involved in a task, and distracts him from the objective Games, therefore, are most useful as they help the patient to focus his attention on the end-result required and to forget his disability

Competition

Competition distracts from the pre-occupation of inefficiency, pain and monotony Furthermore, in a motional game the pattern is unconsciously planned in the mind before being translated to the hand and arm for performance It is wise, therefore, to differentiate between games which are primarily concerned with building up power, tolerance, and reflex response, and those which need planning and specific patterns of movements of hand and mind Both types may be necessary

Spontaneous stimulation of muscles and joint function

The most fundamental necessity to produce maximum effort is some sort of incentive This may take the form of absorbed interest in the immediate objective, the enthusiasm of competition, or a longer view of getting back to work as quickly as possible One patient, having had a tendon graft, had to be fit by a certain date in order to be able to get his posting overseas which he badly wanted The time given was shorter than it normally takes for reasonable function, but he worked so well at his treatment that his object was attained Constant stimulation of interest, variation of methods to obviate boredom and monotony, explanations which allow a patient intelligent appreciation of why such methods are being used, charts of progress by which the patient can follow a step-by-step goal to be achieved, are all necessary at one time or another to promote recovery

Broad analysis of well-known table games

Games which can be used for patients with the arm supported in a sling with spring assistance or counter weight

Draughts	Pelmanism (patience size)

adduction and abduction of the fingers, the neck of the bulb is held between the index and middle fingers with the thumb on the crown of the bulb (Fig 92)

Flip football

This game is useful for extension of the metacarpo-phalangeal joints and wrist, and is similar to blow football in all but the apparatus used In place of the bulb a square leather bag is made to fit over the patient's hand to cover the fingers and grip above the metacarpo-phalangeal joints The bag should be at least 2 inches longer than the fingers, and should not be too stiff—plenty of extension is needed to carry the momentum of the leather " flip " action

Finger extension is used for play, and only the edge of the leather is allowed to touch the board otherwise the fingers will be used to push the puck (a flat puck is used in place of the ping-pong ball) instead of using the " flip " action

Flower pot and marbles

This competitive game is used to encourage a weak grip, pronation, supination, co-ordination, and speed

Articles necessary are a 9-inch flower pot, a wooden spoon, 24 marbles, or wooden beads about the size of marbles, and a watch with a second hand

The flower pot is placed upside down in the lid of a strong cardboard box or wooden tray with the rim about 2 feet long The marbles are scattered into the lid around the flower pot, and with the wooden mixing spoon the patient scoops up as many marbles as possible and tries to pour them through the hole in the pot within a given time At the end of this time the marbles within the pot are counted

SERIAL PLASTER STRETCHING

Aims

Serial plaster stretching aims at maintaining the hand in a good functional position, correcting deformity, and resisting stress strains on tendon, ligaments and capsule caused by paralysis or deformity They should not supplement lively splints, and should be used during periods when the hand would normally be at rest The times of application must be strictly adhered to and co-ordinated in the patient's treatment routine

Maintenance of maximum stretch obtained in physiotherapy at each session is another use of serial plaster stretching

Materials required

The following bandages and equipment are necessary in serial plaster stretching

(1) Plaster bandage when the splints need to be changed daily

(2) Polythene when only a night splint is needed

(3) Plaster bandages size 3 inches and 4 inches

(4) 2-feet-square table, covered with white waterproof material, such as American cloth or jaconet, and padded slightly for the patient's comfort

(5) A stool for the therapist, slightly higher than the chair used by the patient

(6) A table on which are placed plaster bandages, cotton-wool, crepe bandages, lubricant, a bowl approximately 12 inches in diameter for warm water, and a receptacle for discarded paper wrappings

The therapist sits opposite the patient, either side of the table The patient should rest the whole forearm on the table so that the forearm and hand are fully relaxed



FIG 92 —*Blow football*

Construction of the pitch

A table constructed with a rim all round, approximately 5 × 3 feet, can be larger or smaller according to the space available

Corners should be rounded, otherwise the ping-pong ball is inclined to get stuck in a corner

Markings and goals can be similar to those on a football field, and rules as judged suitable by the therapist to the needs of the patients

The bulbs are those used for drawing up distilled water, and can be bought at a garage tool shop For much lighter work for the hands, bulbs used by florists for spraying flowers are recommended

Action

Free action round the table is best as this allows movement of the whole limb as well as the hands, and has been found to give more feeling of competition

Players

Four people (or two) can play Tournaments can be arranged

Timing

Fatigue is quickly built up, it is essential, therefore, that the therapist herself first plays this game to be able to assess the length of time to be allowed each patient As a guide, the first efforts should not exceed 1 minute, $\frac{1}{2}$ a minute one way, and a $\frac{1}{4}$ of a minute is played with the normal hand, then the bulb transferred to the affected hand for the last $\frac{1}{4}$ of a minute

Positions of holding the bulb

(*a*) In the palm of the hand for all types of grip and general muscle work

(*b*) For encouraging action in the long and short flexors to the thumb and

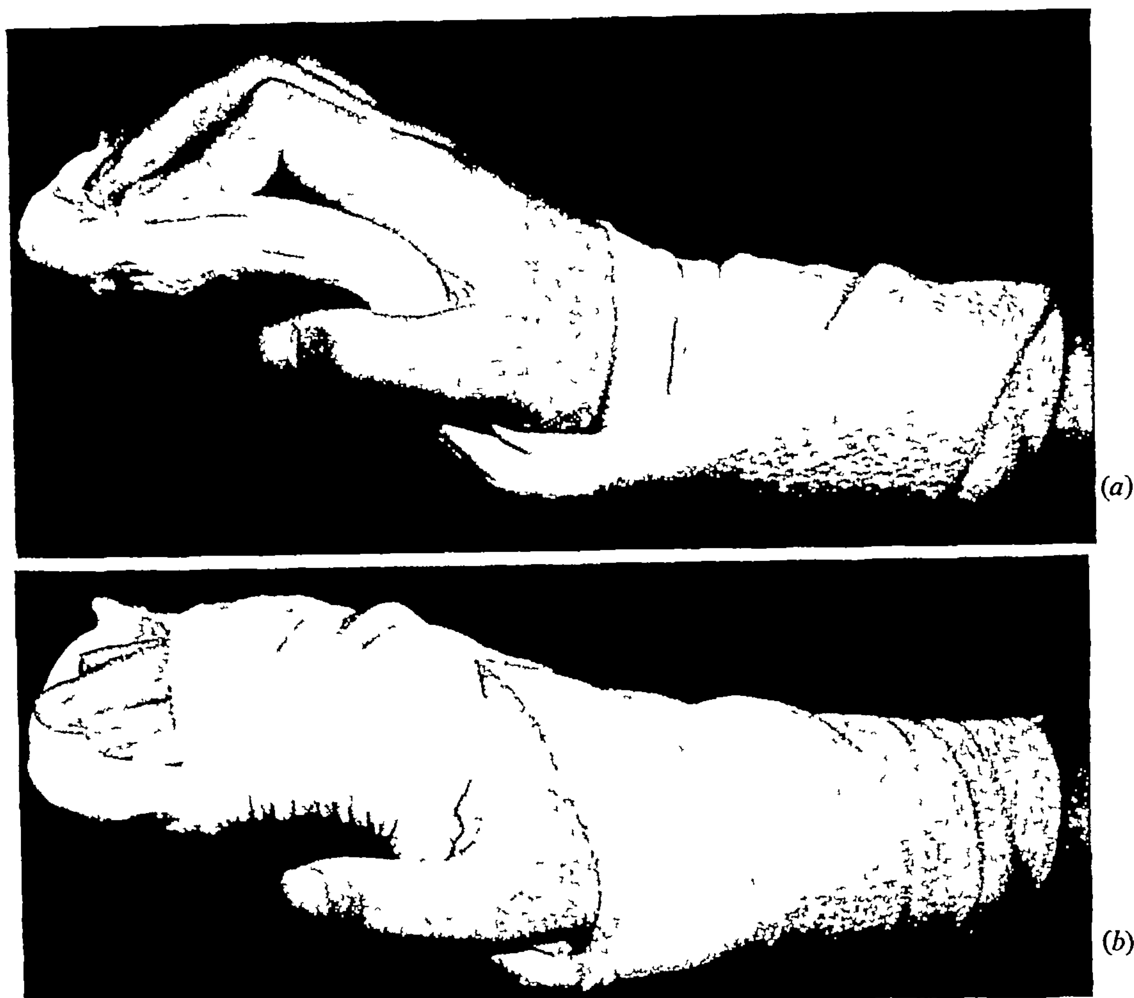


FIG 93 —(a) *Position of the hand in a case of contracture of flexor tendons at the wrist before application of a stretch splint* (b) *Position in splint showing the degree of correction of the deformity*

The splint is then dried under a lamp, and should, when possible, be warmed before being applied to the hand A lining should be supplied with the splint, but preferably not of cotton-wool as this is not always easy to apply evenly, thus causing incorrect posture, patients may also continue to use the splint when the cotton-wool has become lumpy Woollen material, such as clean discarded hospital blanket, is recommended for this purpose as it affords protection against over-heating of the splint, which may happen at the patient's home

A layer of cotton-wool is then placed over the posterior aspect of the hand, and the hand and forearm are bound with a crepe bandage in the usual manner—from the finger-tips towards the elbow The extra cotton-wool is really a protection against a bandage too tightly applied by the patient in his own home, if he is under constant supervision the cotton-wool is not really necessary

STRETCH SPLINT FOR ULNAR NERVE SUTURE AND TENDON INVOLVEMENT WITH WRIST FLEXION CONTRACTURE

The wrist and fingers are examined to decide on the maximum stretch needed at the wrist which will allow the ring and little fingers to lie in a correct postural

Principles of technique

It must be remembered that in plaster stretching the operation is performed more or less " blind ", and that a great deal of harm can result from an indiscriminate stretch It is inadvisable for an inexperienced person to attempt this type of treatment, though " resting " plasters involving correct posture only can and should be taught to the less experienced as a step towards this Special care is needed when a nerve suture is involved

It must be quite clear to the therapist whether the contractures are due to (*a*) shortening of structures round the joint, (*b*) shortening of tendons through their full length, (*c*) scar tissue binding down the area involved and inhibiting full movement of the structures within the area, or (*d*) a combination of all these factors

The therapist must understand perfectly the difference between a stretch and a manipulation

It is wise for the therapist to treat the same patients at each session, but if this is not possible detailed notes and, in the case of fractures, drawings or radiographs should be available

Under no circumstances should the treatment of a particular patient be passed on verbally

At each session the hand and forearm should be carefully examined

Observations

It is necessary to note the following the condition of the scar, the quality of the circulation, the posture, the range of all joints; the tendon lengths, the area of adhesions, the stretch and spring of contracted joints and of tissue adhesions

NIGHT RESTING SPLINT FOR CORRECT POSTURE

The length of the splint (Fig 93) should be from the tip of fingers to within 2 inches of the elbow crease, as anything less than this is apt to dig into the forearm at the edges and cause the patient discomfort Two 4-inch bandages should be folded to this length, and to about 8 thicknesses These should now be dipped into warm water, and gently squeezed to remove surplus water, straightened and smoothed so that there can be no areas likely to cause skin friction

The splint is made over the anterior aspect of the forearm and hand

The forearm and hand should be placed in a comfortable position on the table, palm facing upwards, and the plaster laid over the full area It is then moulded to the shape of the forearm and palm of the hand, and the area of plaster over the thenar aspect is folded back into the palm The metacarpal is abducted and opposed, passively if necessary, to prevent the plaster pressing down on the thenar muscles The patient then flexes the elbow enough to allow gravity to assist a mild wrist extension, thus freeing the therapist to position the rest of the hand correctly The metacarpo-phalangeal joints are put into slight flexion and the fingers comfortably curved In the case of a median nerve lesion, an extra piece must be added from the front of the plaster about 4 inches above the wrist, curving round the posterior aspect of the metacarpal and up the medial aspect of the thumb to hold it gently abducted and rotated This is more satisfactory than a wedge across the palm pushing the thumb into abduction

Many of these points may seem small and unimportant, but long experience has proved them essential

There is a tendency for some patients to look upon these plasters as the main part of their treatment, and to wear them at all possible times Efforts should be made to impress upon them exactly the amount of time the medical director wishes them to be worn

Plaster Stretches for Fibrous Adhesions caused by Crush Injuries

Indications

Plaster stretches are indicated in (*a*) restricted range of movement of the thumb, (*b*) restricted range of movements of the wrist involving carpo-metacarpal joints, usually associated with palmar adhesions, and (*c*) crushed fingers which have been left too long without physiotherapy, bad plasters restricting finger movements, simple fractures of the fingers not involving the joints, but stiff through adhesions and capsular contractions

Principles of technique

These stretches should be started as early as possible, if no fracture or nerve lesion is present

The serial stretch should be taken in all the normal joint ranges so that the line of adhesions resolving follow the different ranges of movements This is especially important in regard to the thumb

They should not interfere with the physiotherapy treatment, nor well-progressed occupational activity, but should be an adjunct to them They are not safe if a patient is not to be seen for several days, as circulation and pressure points need careful supervision

The ideal routine is for the patient to have physiotherapy, followed by occupational therapy, returning to the physiotherapy department for a last stretch before having the plaster applied

Plaster stretch for fixed adducted thumb

Adhesions in this condition can be simple or multiple, which depends, of course, on the type and severity of the injury However, even the less severe type will prevent the axial rotation of the metacarpal, and the serial plaster stretch must be varied to follow the different positions assumed by the thumb The most severe adhesions can usually be palpated, and the first assault is made on the most restricted of these ranges

The following are points to be observed before applying the plasters (*a*) the time since injury, (*b*) the condition of scars, if any, (*c*) the condition of circulation and amount of oedema present, (*d*) the age and intelligence of the patient, and (*e*) areas of tenderness and anaesthesia

Note —Patients with hyper-aesthesia sometimes find the heat generated by the plaster too hot to bear If this is the case, a piece of stockinette is applied before putting on the plaster If this is not enough the plaster must be eased away from the skin enough to allow air to pass between the two areas It is possible to hold the stretch in place while doing this If the patient can stand the heat stretches are more successful

Time since injury

If application is possible soon after injury, the full length of the thumb range

position; that is, not hyperextended at the metacarpo-phalangeal joints, and the interphalangeal joints fully extended

The amount of stretch decided upon should be in relation to the patient's own active movements at the wrist, disregarding the functional deformity of the ring and little fingers as he performs the movement As the first effort is usually less than the maximum effort, the procedure should be carried out with the patient sitting directly in front of the therapist who should place her thumb in the palm of the patient's hand (the therapist's right hand if the injury is left-sided) and her fingers round the patient's wrist, follow the wrist extension as far as it goes, then allow the patient to relax completely, holding the achieved position with the thumb This procedure should be continued until the therapist is assured that the patient has achieved the maximum effort

These are the basic safety rules for a stretch plaster in which a patient is going to rest, perhaps for some hours, but experience will dictate whether the amount of spring still left at the wrist, or the pull on adhesions, will allow for a little further passive movement It must be remembered that pull on adhesions, over a period of time, can obstruct the circulation, and it is best to err on the side of caution, bearing in mind that the aim is to maintain the amount of stretch which has been achieved by physiotherapy that day, and no more

The method of application of the splint itself is similar to the one already described, but special care must be taken to ensure that the metacarpo-phalangeal joints are in flexion and the two fingers straight There is one point to be considered when applying the splint, and which should be explained to the patient if he has to apply it himself at home The splint is put on the forearm and hand, and two or three turns made round the wrist first, but lightly, only to hold the splint in place, the therapist then places her fingers across the proximal phalanges of the patient to give them support while *the patient* actively straightens his fingers onto the plaster assisted by the therapist, these are then held in position while bandaging of the hand is performed As the bandaging arrives at the wrist, the patient is asked to extend the wrist himself while being assisted In this way one avoids the stretch reflex when trying to stretch the hand on to the plaster

Combined Ulnar and Median Nerve Suture, with Multiple Flexor Tendon Contractures

The procedure is very similar to that described for ulnar suture, but the additional resting piece for the thumb must be included, and care must be taken to see that all the metacarpo-phalangeal joints are not allowed to hyperextend, at the same time slightly " lifting " the fourth and fifth metacarpal in a plane in front of the second and third as can be seen in the normal hand There is often a great tendency for all the fingers at the metacarpo-phalangeal joints to deviate ulnarwards in this combined lesion and this must be corrected on the splint In making the splint this tendency will very often weigh down the plaster on the ulnar side in spite of one's efforts to avoid this, as there are so many things to do in the short time for setting Therefore, immediately the splint is removed there is usually a split second of time when a quick twist will bring it back When this deformity is very evident it is usually advisable to add partitions between the fingers to keep them strictly in position

abduction, the third into more acute opposition, and so on In this way the adhesions are stretched in the various axial movements

FINGER STRETCHES

Indications

Finger stretches are indicated in the following (*a*) tendon grafts in which recovery of movement is held up by adhesions, (*b*) terminal interphalangeal joint contractures, (*c*) stiff joints due to prolonged splintage, (*d*) Dupuytren's contracture following surgery, (*e*) fractures into the joint, (*f*) scarring in the palm causing finger contractures, (*g*) soft-tissue contractures after joint dislocation, and (*h*) contractures following skin grafts

Principles of technique

Plaster stretches are not necessarily always indicated in the above conditions Physiotherapy alone will, more often than not, deal with the condition adequately, but when progress is not being maintained, plaster stretches are applied

Method

In this group it is difficult to conform to hard and fast rules as each condition must be assessed on its own merits The principles to be followed are those already laid down to be clear in one's own mind as to the type of contracture and the exact site necessary to be stretched In flexed fingers it is more often than not a single joint which is fixed and the traction should be concentrated above and below this area

Economy of plaster area is an aim to be kept in mind. It is wise to use only enough plaster to do the job and not restrict movement in unaffected parts of the hand if this can be avoided

Dupuytren's contracture

The following account is based on the treatment of *Case 2*, Chapter 2, page 31

On examination the contractures lay mainly in the palm of the hand, with some limitation in wrist extension and 90 degrees limitation at the proximal interphalangeal joint of the ring and little fingers This was considered to need a full stretch plaster throughout the hand and the wrist The unaffected areas were the thenar muscles, the index and middle fingers, and therefore the plaster should not interfere with their movements Plaster bandage was folded to reach from the tips of the affected fingers to 6 inches below the wrist The whole area of the hand was greased to avoid skin dryness due to the constant application of plaster as well as to prevent catching any hair

After wetting, the bandage was folded back lengthways over the finger area to avoid the normal fingers, the fold reaching down into the hand from the thenar eminence allowing an almost complete range of thumb movement

The plaster was applied to the hand and wrist and moulded into place allowing enough room beyond the fingers for the increase in length as the area was extended As setting point approached, the patient was asked to straighten out the hand and fingers and extend the wrist Meanwhile, the plaster was held in place over the whole area, gently continuing to mould the plaster as the surface area changed

can be maintained by frequently changed plasters, but great care should be taken to ensure that circulation is not disturbed as oedema will still be present, and to ensure that further trauma is not caused by undue stretching

If some time has elapsed and contractions and adhesions have already formed, the emphasis will be on vigorous stretching with strict supervision of pressure points

Condition of scars

Consideration must be given to the condition and position of scars Plaster will not, of course, be applied until stitches, if any, are removed, nor if scabs are still present Stretches must not be taken in a direction which will pull against two edges of tissue not completely healed Tender skin areas must be well covered before applying the plaster

Condition of circulation and presence of oedema

If oedema and disturbed circulation are present, plaster should only be applied if the patient is under constant supervision The patient should be made aware of the possibility of changes of colour and increase of swelling and told to report either of these conditions immediately If he is returning to a ward the sister in charge should be informed of the necessity of observation

Age and intelligence of the patient

Where there has been a lapse of time since injury, and where oedema and disturbed circulation are present, the age and intelligence of the patient are particularly important A child will have little notion of what is really implied by change of colour and will probably not notice the swelling

Areas of tenderness and anaesthesia

It is important to know exactly the site of all the areas of tenderness, so that when using one's fingers to stretch, efforts can be made to avoid pressing on these areas and causing the patient unnecessary pain

If anaesthesia is not present the patient can tell the therapist if the plaster is chafing and causing discomfort, in the event of anaesthesia being present, it is specially important to be quite sure that this is not happening as blisters will result If any doubt exists it is as well to insert a tuft of cotton-wool to be quite sure no harm can result

Method

The materials required are a 4-inch plaster bandage, a 3-inch crepe bandage, Vaseline and cotton-wool

Fold the plaster bandage into about 10 layers to form a 5 to 6 inch pad Make another small roll of bandage to act as a wedge The pad is applied over the web of the thumb, the folded ends facing the index finger and thumb The plaster is then moulded over the thumb metacarpal joint and the index finger At setting point the metacarpal is raised away from the palm by pressing the index finger and thumb metacarpal away from each other in the direction indicated The plaster is pressed into place to maintain this stretch, but care must be taken to ensure that pressure is evenly distributed

Just before the plaster finally sets, the wedge is inserted into the web area of the thumb to add to the strength of the plaster If the first plaster takes the thumb to right angles to the palm, the second should be a few degrees towards radial

PLASTER CASTING AND MOULDING FOR ANY SPLINT REQUIRING ACCURATE SHAPING

Technique

This is the technique used for plaster casting or moulding leather or Perspex for small areas of the hand The thumb is used as an example

Cut 2-inch squares of plaster bandage Grease the dorsum and palmar aspect of the metacarpal and further up the thumb if required Place the thumb in the position required, usually the position of function Place about 6 layers of wet bandage over the whole area to be covered If a complete replica of the thumb is to be made this must be done in two parts half the curve made, allowed to set for a few moments, then the edges greased, and the rest of the curve completed The edges must overlap the greased portion so that the two can be taken apart and set together again for taking the " positive "

The plaster is removed from the patient's hand and it is termed the " negative " Having first marked round the inside with a coloured pencil to facilitate recognition of the removal edge, the inside of the plaster is well greased then spread with layers of bandage—the first few layers being applied very smoothly—until the whole negative is nearly full It is then put under the lamp to dry out, and the negative is removed from the positive, leaving a replica of the original area of the hand

Moulded leather

Tanned hide is most suitable for this purpose A piece is cut to roughly the shape required but greater in size and is placed in a bowl of water for a few moments until it is soaked through, and is then placed in a cloth to pat out the surplus water The leather is stretched in all directions before applying to the mould It will probably be found that the leather stretches more in one direction than the other and this line of " restricted stretch " should be applied over the mould on the line of restriction required, for example, if it is metacarpo-phalangeal joint flexion to be restricted the line will follow along the length of the metacarpal to the mid-line of the terminal phalanx

The leather is then moulded firmly over the cast, pressing strongly with the thumbs until every contour shows up well on the surface of the leather A thin layer of cotton-wool is then placed over the surface and the whole is bandaged firmly to the cast It is then placed under the lamp and dried out quickly If milder heat is applied the leather will not harden sufficiently, on the other hand, it must not be allowed to scorch or it will become brittle When the leather is applied to the hand it must have a thin but soft lining

If Perspex is to be added to the leather for further restriction, the following addition is made On the cast mark the exact area to be covered by the Perspex, a paper pattern is taken and the Perspex is cut to shape A piece of the same leather is cut a little larger than the Perspex, soaked and moulded over the area which the Perspex is to cover The cast with leather and Perspex placed on it is placed under a hot lamp 8 inches away until the Perspex is soft enough to mould If the therapist wears leather gloves and works quickly, no discomfort should be experienced The Perspex must be held in place away from the lamp for a moment or two as it is inclined to spring as it hardens When it is cool, small holes can be drilled in positions suitable for attachment to the leather

This active movement made by the patient was held by the therapist, and the patient told to relax. Another active effort was made by the patient, this time aided by the therapist, and as the patient relaxed the stretch was applied to the joints and the palm, this was held in position until the plaster was set to maintain the position. A pad of cotton-wool was applied to the dorsum of the hand and wrist, and without letting the hand spring away the plaster was bandaged firmly to the hand and wrist.

The patient had physiotherapy 4 times a day, and the plaster was applied after the second treatment and left on for 1½ hours. A fresh plaster was applied after physiotherapy and occupational therapy at 4.30 p.m. and was left until 7.0 p.m., the same plaster being re-applied on retiring to bed.

Stiff index finger due to trauma

The following account is based on the treatment of *Case 2*, Chapter 5.

Weakness of the whole hand was present but responded to normal full-time treatment. The index finger, however, failed to keep pace with the rest of the hand and stretch plasters were therefore prescribed. As flexion was inhibited the plaster was applied over the dorsum of the finger. A 3-inch bandage was used but folded to 1½ inches, the length reaching from the tip of the finger to the wrist, allowing 1 inch for increase in length as the finger was bent. Patients generally find it much more painful to have passive stretches to the extensor aspect of the fingers than to the flexor and can tolerate plaster stretches for a far shorter time. This must be taken into consideration when planning the routine. Also, the nail-bed is much less tolerant of pressure than the pad of the finger tip.

On examination it was found that the metacarpo-phalangeal joint was fairly mobile, but that both proximal and terminal interphalangeal joints had very limited flexion.

A small pad of chiropody felt was placed over the nail. The plaster was applied over the dorsum of the hand and finger, moulding the plaster to enclose both sides of the finger. The metacarpo-phalangeal joint was placed in flexion and the patient was told to flex his fingers actively. This was held in position while the patient relaxed and then tried again. On the third attempt of active flexion, assistance was given, and on relaxation a further passive stretch was given. The last stretch must be within the patient's tolerance, as it is not a diminishing tenderness, though the more acute pain will disappear as the plaster generates heat.

When applying the stretch the tip of the finger must be held on the side of the nail-bed and not directly over it. The felt will help to prevent undue pressure and thus obviate unnecessary pain to the patient.

It has been found wise to retain these plasters for a progressive length of time, starting sometimes with as little as 15 minutes.

Summary

Although serial plaster stretching has been found of great value it should be regarded as a skilled operation and used only by experienced operators. Harm can be done by over-stretching, wrong pressures, careless application and lack of supervision.

(Trunk bent forwards, arms bent) alternate arm punch towards floor
(Arms bent) alternate arm punch forwards with trunk twisting

Arm flinging

Examples of exercises

(Arms across bent) arms flinging sideways
(Arms sideways) arms flinging (bend and fling in one movement)
(Arms across bent) elbow pressing backwards with arms flinging sideways on every third count
(Arms across bent) alternate arm flinging sideways with head and trunk turning left and right

Arm swinging

The movements in these exercises are performed with the arms stretched and then swinging them in a named direction It should be a free and easy movement with the fingers normally loosely clenched These exercises mobilize the shoulder joint particularly, and are normally performed rhythmically

Examples of exercises

(Arms sideways) arms swinging downwards and forwards
Arms swinging forwards, and forwards and upwards (later with heels raising)
Rhythmical arms swinging forwards and backwards with increasing range to reach arms upward in 8 counts
Arms swinging sideways, and sideways and upwards to clap the hands above the head
Upward jump with arms swinging forwards and upwards
(Feet astride, arms across) rhythmical arm swinging midway upward with heel raising
(Feet astride, arms sideways) arms swing forwards to clap the hands and return to press backwards with 3 presses in position
(One arm stretched upwards) arms changing with a swing

Arms circling

Examples of exercises

Free arm circling
(Arms sideways) arms circling—small circles at first increasing and decreasing in size
" Shoulder loosening "—shoulder circling (lunge position), that is, with one foot placed forwards and sideways One arm circling forwards and backwards
Bowler's arm action
(Feet astride) arms circling in opposite direction simultaneously
(Feet astride, trunk slightly forward) front crawl arm stroke

To increase the co-ordination necessary and to make the exercise more difficult to perform, various combinations of the above group can be used Also, to improve co-ordination these arm exercises may be performed in conjunction with leg, trunk, abdominal or other exercises

Examples of exercises

Arms swung midway upwards and swung sideways and downwards and back to midway upwards in one movement
Arms swinging forwards and sideways with alternate foot placing sideways
Astride jumping with arms raising alternately forwards and sideways
Arms swinging forwards and sideways and circling with a jump
(Feet astride) arms swinging forwards and upwards 4 times, quickly, followed by arm circling slowly 4 times

Hand exercises

These are for the long flexors and extensors as well as the intrinsic muscles of

Suppliers of materials used in making lively splints

Buckles, " D " rings, press studs, rivets —Nottingham Leather Co , Trivetts Buildings, Glasshouse Street, Nottingham, and Arts and Crafts (Doncaster), High St , Doncaster

" *Foamoprene* ", *white plastic lining* —Kay Brothers Plastics, Hurst Street, Reddish, Stockport

" *Vitrathene* ", *polythene sheeting* —Stanley Smith & Co , Worple Road, Isleworth, Middlesex

Tanned hide —A E Holmes, 52, Streatham Road, Mitcham, Surrey

Hinges for splints —Supplied by Local Government Training Centre, drawings from Ministry of Labour and National Service, Government Training Centre, Stafford Road, Waddon, Croydon

Rubber sheeting for splint used in thenar paralysis —Messrs Sorbo Rubber Co , Ltd , Woking, Surrey

Sponge sheeting, " Starco " quality, $\frac{1}{8}$ inch thickness —The St Albans Rubber Co , Ltd , The Camp, St Albans

Rubber bands and suckers for nail brushes —Canton Ltd , Mermaid House, 70, St Thomas Street, London, S E 1

REMEDIAL EXERCISES AND GAMES

The following activities are suitable for gymnasium work and are usually given under the supervision of the remedial gymnast

It is a good plan to have the general exercise periods to music, Scottish country dancing and the like being preferred to rock and roll

General arm exercises

Arm exercises can be divided into various groups and each group has its own particular function with regard to muscle work The groups are (*a*) arm stretching, (*b*) arm punching, (*c*) arm flinging, (*d*) arm swinging, and (*e*) arm circling

Arm stretching

These exercises are normally performed from a position of " arms bent ". The arms are then stretched in various planes, forwards, sideways, upwards, and downwards They are exercises in co-ordination, particularly when they can be performed asymmetrically

Note —In examples the starting position is always given in parentheses, for example (arms bent) If an alternative position is not mentioned, it is assumed that the exercise is performed in a standing position The return position is assumed to be the same unless stated otherwise

Examples of exercises

(Arms bent) arm stretching sideways, followed by arms stretching forwards

(Arms bent) arm stretching upwards twice and sideways once

(Arms bent, fists clenched) slow arm stretching upward and quick arm bending (stretch fingers at end of upward stretching movement)

(Arms bent) alternate arm stretching upwards and downwards

(Arms bent) arms stretching forwards, sideways and upwards with one arm leading by one count

(Arms sideways) arms bending and stretching alternately in one count and two counts

(" Star jumping ") jumping high with wide stretch of arms and legs

Arm punching

Examples of exercises

(Arms bent, fists clenched) alternate arms punching forwards and upwards

(3) Two poles as above Arms raise sideways and upwards. (Grip)

(4) Two poles as above Arms swing forwards, backwards and circling (Grip)

(5) Two poles as above Try to push partner backwards by pushing on the poles Also try to pull partner forwards using the poles (Grip)

(6) In pairs facing one another, both partners grasp one pole—one at each end Twist clockwise or anti-clockwise against partner's resistance Change to tug-of-war—same grip—also pushing partner over a marked line (Grip)

(7) Pole upright on floor, both partners grasp the pole with two hands Pole twisting against resistance of other partner (Grip)

Ball activities

All the activities listed below are to encourage the patient to use his hand, the elbow and shoulder, and the intrinsic muscles of the hand

Throwing balls into a basket or circle
Knocking down skittles with balls
Rolling balls between obstacles or lines
Aiming at a wall target—overarm or underarm
Bowling at wickets
Aiming to the left or right of a partner who catches
Aiming a ball through a hoop or at a suspended object.
Bouncing a ball with the hand

Games suitable for the late stages of hand injuries

"*Keep the ball moving*".—Two teams try to get as many consecutive passes amongst themselves as they can without interception

"*Intercepting in threes*" —Two players pass the ball while a third player in the middle attempts to intercept it

"*Ball tag*" —One player, chosen as the chaser, throws the ball at the other players until he hits another who then becomes the chaser

"*Dodge ball in threes*" —Two players aim the ball to hit a centre player below the waist The one in the centre dodges and jumps to avoid being hit

"*Circle dodge ball*" —Players form a circle A number of players are put in the middle and the players in the circle throw the ball to hit those in the centre below the knee When hit the dodgers join the circle

"*Wandering ball*" —Players form a circle with one or more in the middle The ball is passed or thrown about the circle and those in the centre try to intercept it The interceptor takes the place of the player who throws the pass

"*Tower ball*" —A skittle is placed in the middle of a chalk circle One player defends the skittle while the others aim to knock it over by throwing the ball at it The defender uses hands, body and feet to defend the skittle

"*Hand ball*" —The rules are as for football, but the hands are used

"*Bounce hand ball*" —This game is identical to football except that the hands are used, and the ball must be bounced continuously

Miscellaneous activities requiring special apparatus

Games useful for grip and re-education of intrinsic muscles.

"*Quoit tennis*" —This game requires a net and circular rope rings and a tennis court marked out The object is to throw the ring over the net to touch the floor before the opponents catch it

the hands They can be performed while the patient is seated with arms forward or elbows resting on the knee

Examples of exercises

Hand bending upwards and downwards
Hand bending from side to side
Hand rolling or circling
Finger parting and closing (all 4 or any 2 parting at one time)
Making a fist and finger extending
One finger flexing and extending
Touching each finger tip with the thumb in turn (opposition)
Thumb circling

All the exercises mentioned are formal exercises done without the use of any apparatus or aids of any kind To keep the patients' interest and to vary the programme as well as to give assistance and sometimes strength to the exercise, various pieces of apparatus may be used These should not be complicated A pole about 5 feet in length and about 2–3 inches in diameter is most useful

Exercises with poles

(Starting positions are given first)

(1) Hands shoulder width apart, overgrasp the pole, elbows bent, forearms parallel to the ground Twist the pole inwards using both hands Change to palmar and dorsiflexion Then change to twisting the pole outwards Repeat with undergrasp (Grip)

(2) Grasp the pole in the centre with one hand, holding it vertically Rotate the pole to the left and right giving maximum pronation and supination (Grip)

(3) Arms stretched upwards, the pole is held up with the fingers and thumbs "Walk" with fingers and thumbs to end of pole until pole rests on the back of the neck Then reverse procedure (Intrinsics)

(4) One arm sideways, grasp the pole at the centre, held vertically Raise the pole over the head, change hands and lower to the other side continuously (Grip)

(5) One arm forward, grasping the pole at the centre Rotate the pole clockwise until maximum movement achieved, then change hands and continue changing to keep the pole rotating Repeat in anti-clockwise direction (Grip, pronation and supination)

(6) Arms forward, grasp the pole with the hands shoulder width apart. Rotate the pole and allow both hands to travel to the end of the pole while keeping it horizontal Then change direction of twist and travel to the other end of the pole (Grip)

(7) Overgrasp the pole with both hands Pole circling (Grip)

(8) Grasp one end of the pole with both hands, with the other end resting on the floor in front of the patient Raise the pole horizontally followed by arms bending and stretching (Grip)

(9) One arm forward grasping the pole at the centre—the other arm forward Throw the pole from hand to hand (Intrinsics)

(10) Grip the pole with both hands, rotate it, providing opposition by twisting the hands in opposite directions (Grip)

Activities using poles in pairs

(1) In pairs facing one another, two poles, both partners grip both poles at ends Swing arms alternately forwards and backwards with straight arms (Grip)

(2) Two poles as above Imitate pistons (Grip large ends)

This is devised to warm up and exercise the whole body

9 15– 9 45 a m	Remedial exercise period in the gymnasium in class with remedial gymnast
9 45–10 30 a m	Physiotherapy
10 45–12 15 a m	Occupational therapy
1 30– 2 00 p m	Remedial exercises
2 00– 2 45 p m	Physiotherapy
2 45– 4 00 p m	Occupational therapy
4 00– 4 30 p m	Physiotherapy

Most patients in these centres find that not only does the regime make them feel fitter than they have felt for a long time, but this in turn accelerates the recovery of their local lesion

The value of such centres was amply proved by the speed with which patients with fractures, dislocations, burns and nerve injuries were returned to work and, furthermore, by the high proportion of patients with good functional results

Civilian

Many civil centres have been developed throughout Great Britain since World War II, including special centres for miners, centres attached to general hospitals like Harlow Wood, and centres serving several hospitals and taking all types of case, such as Garston Manor and Farnham Park At the Vauxhall factory an exciting new development has been in successful operation for the last few years Here a special part of the factory known as the rehabilitation workshop is set aside for patients who work on machines devised to increase range of movement in stiff joints and build up the power of weak muscles A patient with a fracture of the lower limb need be off work for only a few days, as work can be found for him in the rehabilitation workshop on a suitably adjusted machine He thus obtains treatment and continues to carry out productive work in his normal environment (Thompson, 1949)

The most recent centres are the rehabilitation department of the Salisbury General Infirmary and the Medical Rehabilitation Centre in Camden Road, London Both these centres deserve a little more detailed discussion At Salisbury, the rehabilitation department is situated a few miles from the main hospital and comprises a small occupational therapy department, a gymnasium, and a workshop equipped with up-to-date lathes and other machine tools The patients are thus able to have all forms of physical treatment and to undertake work in order to improve their function The work is sub-contracted from surrounding firms and is devised by the engineer in charge of the department, in consultation with the doctor, so as to be adapted to any particular range of movement of a joint, or to increase the power of a particular muscle group on the lines pioneered by Plewes at the Vauxhall Motor Company The machines are so devised that the work can be finely graded from day to day, and indeed from hour to hour

The value of such a centre is that the patients return to the atmosphere of work very early on in their disability, moreover, throughout a long period of their disability, they are working at the job that they normally perform Finally, and perhaps the most important of all, they are being productive and thus do not feel that they are wasting their time or being a burden to industry The spirit in this type of centre is a strong witness of the success of the experiment

In the Camden Road centre, patients attend for a full day's treatment which

"*Jokari*"—This is a game using a racket to hit a rubber ball attached to a long piece of elastic so that it returns rapidly

"*Pick-a-stick*"—A set of sticks of varying colours are released together Each person aims to pick as many of these as possible without disturbing others When he disturbs others his turn ends The various colours have different score values

"*Padder tennis*"—As normal tennis except that it is played indoors with wooden rackets

"*Badminton*"—Normal rules

"*Rope splicing*"

Skipping—turning the rope in the hands

REHABILITATION

Principles

The successful and most efficient method of managing severe hand conditions involves full-time treatment It is hoped that enough has been said in the course of this book to emphasize that anything less cannot be expected to produce the best results Whether treatment is best given as an out-patient at a general hospital or whether attendance as an out-patient or an in-patient at a rehabilitation centre is the best expedient is open to debate There are advantages and disadvantages to each type of treatment centre

It is our opinion, however that some form of special centre where patients with severe hand disorders can work together full-time offers the best facilities An atmosphere of hard work and optimism is preferable to treatment as an out-patient in a general hospital Many patients do better when they are away from home, whilst others, through domestic or financial difficulties, find it impossible to attend other than as out-patients There is undoubtedly a place for both types of centre

The principle of treating patients in a rehabilitation centre rather than in a hospital has an ancestry of some 40 years Sir Robert Jones was the first to provide rehabilitation services for patients following severe fractures, in the Shepherd's Bush Hospital, London, after World War I Here the patients recovered movement in stiff joints and power in weak muscles by performing work that was both therapeutic and productive Between World Wars I and II only a few inspired doctors saw the benefit of a residential rehabilitation centre Moore, in 1925, opened a centre for railway workers at Crewe, and in the years before World War II, Sir Hugh Griffiths performed a similar service for injured dockers

Specific centres

Service

In the early part of World War II, the Royal Air Force developed a number of rehabilitation centres in order to cut down the inordinate time of incapacity that vital members of air-crews were spending with comparatively mild disabilities

In these centres a full programme of remedial exercises, physiotherapy and occupational therapy is given for 6 hours a day, every day of the week Patients with similar disabilities work together part of the day in classes, the work of which is graded according to the site of the disability and the stage it has reached

A typical day for a patient with a hand disability is as follows 8 45–9 15 a m, General exercise period

members of their staffs by providing rehabilitation workshops These are, however, not feasible for a small firm with only a few hundred employees or less

The work of rehabilitation centres would be made considerably easier if the patients undergoing treatment for long periods could perform useful work during their rehabilitation This would necessitate liaison between local industries and the hospital rehabilitation centres, such that a steady flow of work would be available to the patients and could in every way be adapted to improve their function In circumstances where adaptation is not possible it would still be eminently worthwhile as the patients would be earning and working in their normal type of environment This should, incidentally, save the country a considerable amount of money in National Insurance and Unemployment Benefit One has only to call to mind the large number of patients with limbs in plaster for months on end to realize what a large potential source of labour is being wasted

On the whole, patients require supervision for the best results Leighton (1955) pointed out that the best results are obtained by a daily programme of treatment, and that most patients find themselves unable to follow such a programme without close supervision Our experience has amply confirmed this view, and it is particularly true in patients with hand disabilities It is so easy for a patient to perform tasks with his good hand and spare the injured hand altogether

The long period of paralysis in peripheral nerve injuries or the intensive programme of stretching to be undertaken in severe burns can be disheartening enough in a patient in a full-time centre, and it is easy to see why so many lose interest and drift into unskilled labour if only attending hospital once or twice a week

Even when treatment has been ideally carried out and the best result obtained for the particular stage of the disability, it is arguable that continuation treatment should be provided for some months after discharge

Attendance once a week, possibly at an evening clinic if the patient cannot leave his work, will prevent relapses and accelerate the return of normal function

As the hand is the most important part of the body for most people, its disorders deserve the best and most intensive treatment available

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comprises all forms of physical treatment and work in the workshops In contrast to the Salisbury centre which serves the main hospital only, the Camden Road centre will take patients from any part of the regional hospital area, from general practitioners as well as from hospital consultants.

Advantages of special centres

In both these centres and in the other types of rehabilitation centre already mentioned there are certain clear advantages over treatment in hospital, first, the atmosphere of a rehabilitation centre is quite different from that in a hospital—the accent is on recovery and progressive recovery at that There is an air of confidence, optimism, and a close feeling of a team approach that, although present in a hospital, cannot be so obvious to the patient Secondly, transfer to a rehabilitation centre means a quicker recovery and releases urgently needed hospital beds Thirdly, the patient can receive full-time treatment which means that he will get better more quickly and will be given much more detailed and individual attention Problems of resettlement are far more easily solved when the patient can be observed from day to day at various different tasks and his temperament and reaction to his surroundings assessed by the rehabilitation team Fourthly, the mental depression and psychological reaction that accompany any form of physical disability respond much more readily to the atmosphere of a rehabilitation centre with its accent on recovery and the insistence on the patient helping himself to get better and being occupied throughout

The less time the patient has to brood over his disability, the better, particularly in the early stages when he is liable to self-pity and gloomy prognostications about his future work It is therefore advisable to arrange outings of all types and to encourage the patients to make their own amusements, however simple they may be, these often have a remarkable effect in helping the patient to understand himself and to bring out all sorts of latent abilities and interests, many of which are discovered for the first time as a result of serious disability

It is the aim of the director of such a rehabilitation centre to help create an atmosphere which will encourage the patients to be more aware of their new-found abilities than of their disabilities

It is vital at all stages that the patient should understand his disability, what is being done for him, and the suggested plans for his future The first interview and the first impression he gets of the centre is tremendously important Every effort must be made to make him feel welcome, and to feel that the staff are really interested and want to help him to help himself There should be no delay in settling the patients in The sooner they are seen by the doctor and their disability carefully explained to them the better

Siting

The ideal siting of a rehabilitation centre is probably within 10 miles of a hospital, in pleasant surroundings, with sufficient grounds to allow the patients to undertake sporting activities and to relax in the open air, it need by no means of necessity be in the country The consultant staff of the nearby hospital can then visit the centre frequently, and, conversely, the rehabilitation staff can visit the patients and get to know them in hospital before they come to the centre

The whole accent of the work of the centre should be thoroughly realistic and adapted to the patient's future occupation, as discussed in Chapter 10

Firms such as Vauxhall and Austin have solved the problems of the disabled

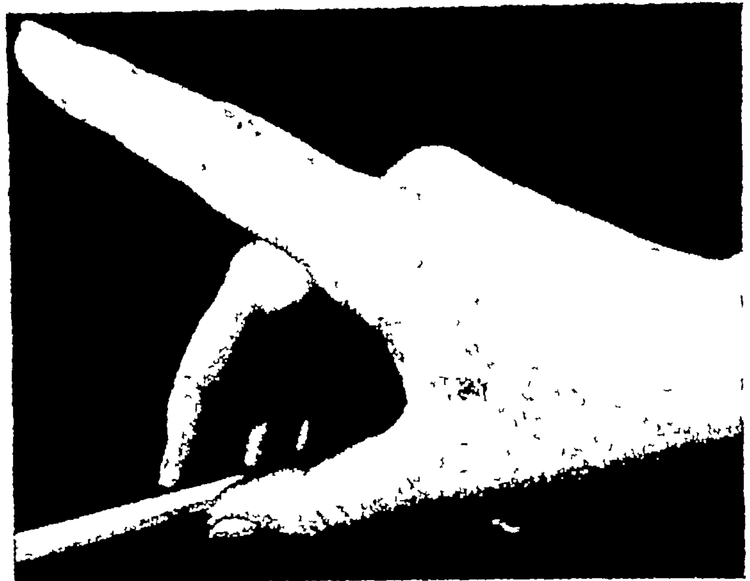
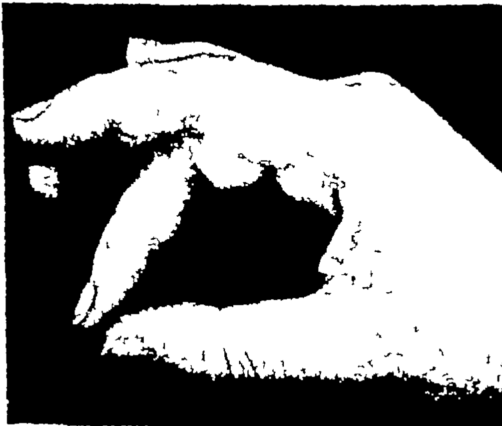
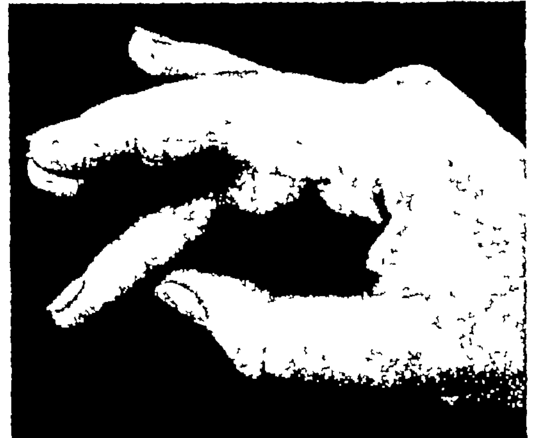


FIG 94—*Opposition of the thumb to the middle finger when the index finger is abnormal*

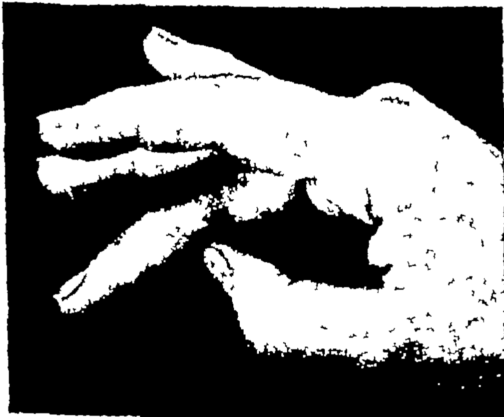
phalanx (Fig 95) Thus, the function of the middle finger can still be very useful, even though part of it is lost, in striking contrast to the index finger (Fig 96) The ring and little fingers can be considered together, as in normal circumstances



(a)



(b)



(c)

FIG 95a, b, c—*The thumb can be opposed to the level of the proximal interphalangeal joint in full rotation.*

they contribute solely to the grip It is true that if the index and middle fingers have been amputated then the thumb will oppose to either the ring or little fingers As great a length as possible of these two fingers is preserved after injury so that they can be curled around the handles of tools

CHAPTER 9

RECONSTRUCTION OF THE INJURED HAND

By DONAL BROOKS

WHAT is your job ? The answer to this question determines to a great extent the programme of treatment of the injured hand In acute injuries it may mean the difference between amputation of a finger and weeks or months of treatment following reconstructive surgery The labourer requires a strong grip, the draughtsman needs precision of movement

What can you do with your hand ? This may reveal a functional capacity far greater than might be supposed It may prevent a great deal of unnecessary surgery after which the patient may rightly feel that the gain in function has not been worthwhile In a similar way the duration of a disability is an important factor For example, a patient with a long-standing paralysis of the thenar muscles may be perfectly capable of writing or sewing by developing a useful pattern of function which might easily be destroyed in an attempt to restore normal movements of the thumb by tendon transplantation This principle is all too often forgotten in the reconstructive surgery of congenital deformities

CAUSES OF DISABILITY IN THE HAND

(1) Loss of part of the hand, (2) loss of active movement, (3) loss of passive movement, (4) impairment of sensibility, or (5) pain

Naturally, in any given hand, the disability may be a combination of all these factors

Loss of part of the hand

The thumb is considered the most important digit in the hand because its great mobility enables the pulp of the distal phalanx to be opposed to that of any of the other four digits After injury to the hand every attempt is made to preserve as much of the thumb as possible The importance of the index finger depends on its ability to meet the thumb and give a pinch grip A pinch grip, however, is dependent upon the lateral stability of the index finger which is derived from the action of the first dorsal interosseous muscle

Opposition of the thumb to the index finger can only be carried out if the index finger is fully flexible and if its length is maintained This means that if the index finger is stiff from any cause, or if it has been shortened by trauma, the thumb automatically opposes to the middle finger when performing precise movements and the index finger is excluded from the usual pattern of function (Fig 94) In other words, unless the index finger is normal in every respect its function is taken over by the middle finger and so its loss may be of no great consequence

The middle finger is important in gripping and for performing precise movements When the opposed thumb has reached the line of the third metacarpal, full rotation has occurred This means that the pad of the thumb can be opposed to the pulp of the distal and middle phalanges and even to part of the proximal

inevitable but in most instances it is due to bad treatment in the early stages It can be prevented by simple measures such as elevation of the limb and frequent passive movements Once joint stiffness is established many months of physiotheraphy and often surgery is required to correct it

Impairment of sensibility

It should be recognized that the highest grade of sensory recovery from nerve repair carried out under ideal conditions can never compare with normal sensibility The methods of assessing sensibility are extremely crude, and although there may be return of light touch and pin-prick sensibility together with two-point discrimination, it is usual to find that such a patient will use the other hand for carrying out fine movements, and will certainly carry his money in the opposite pocket There is little point, therefore, in attempting to restore precise movements in the absence of normal sensibility For example, if an index finger is normal in every respect except that of sensibility, the thumb will oppose to the middle finger, similarly, a thumb with loss of normal sensibility is of little value even though it can be opposed to each finger in turn It is often suggested after injuries of the thumb resulting in amputation at the metacarpo-phalangeal joint that a post should be fashioned by extending the metacarpal and clothing it by a pedicle skin graft Such a post is of little value because it lacks normal sensibility By contrast, the hand severely disabled by poliomyelitis can often be rendered more useful by simple surgical procedures because it possesses normal sensibility

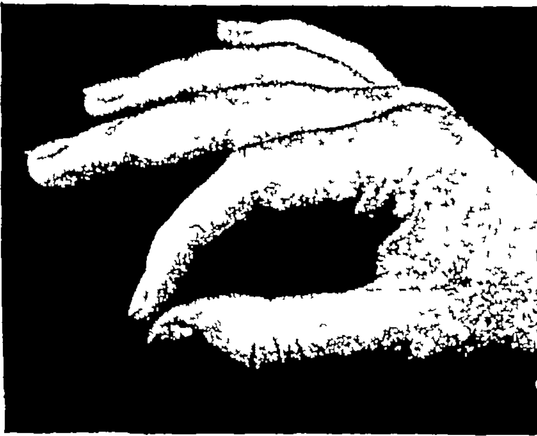
Pain

The treatment of painful conditions of the hand is outside the scope of this chapter

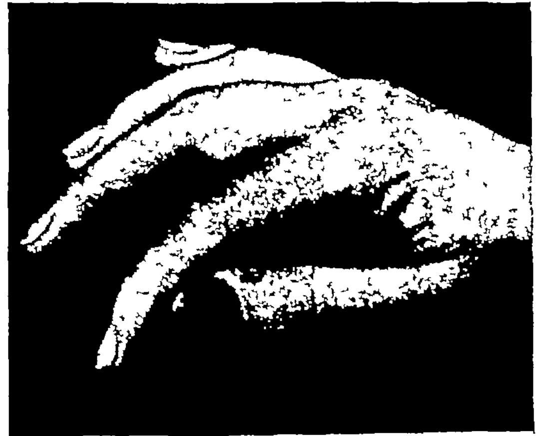
TYPES OF RECONSTRUCTED HAND

From the foregoing it is clear that the aim of reconstructive surgery is to produce one of two types of hand (1) that suitable for performing movements of precision, or (2) that useful for gripping and stabilizing The ability to perform fine movements is associated with normal sensibility in the median nerve distribution and the ability to oppose the thumb to the index and middle fingers The effectiveness of the grip between the thumb and the fingers is to a great extent determined by the strength of the long flexor muscles, but it is dependent for lateral stability on the integrity of the intrinsic muscles It would be fruitless, therefore, to do an opposition transplant for the thumb in a hand in which there was paralysis of the interossei, or in which it was not possible to restore active opposition of the fingers by tendon transplantation Similarly, the value of an opposition transplant for the thumb is greatly decreased if there is impairment of sensibility in the median nerve distribution

If it is considered that at the most the hand will be effective only as a stabilizer, then strong flexion of the digits into the palm becomes important (Fig 97) In such cases active opposition of the thumb is unnecessary and normal sensibility in the hand and fingers is not essential When planning a programme of reconstructive surgery and at all stages during its execution it is important to be quite clear which of the two types of hand is the goal



(a)



(b)



(c)

FIG 96a, b, c —*Full rotation of the thumb can only be achieved when opposing to the terminal phalanx*

Loss of active movement

Loss of movement of the digits may be due to paralysis following lesions of the median, ulnar or radial nerves If possible, restoration of function is established by nerve repair or, where necessary, by appropriate tendon transplantation If the paralysis has been present for more than 18 months it is preferable to choose tendon transplantation because of the inevitable adverse changes that will have occurred in the paralysed muscles Frequently, loss of active movement is due to tendon damage At the level of the wrist joint and in the palm of the hand end-to-end repair of flexor tendons is carried out, similarly, extensor tendons at any level are repaired in this way Where one or both of the long flexor tendons have been divided distal to the metacarpo-phalangeal joint restoration of function is usually achieved by tendon grafting, as direct suture within the digital sheath is nearly always followed by adhesion formation Even in the best hands the results of tendon grafting are not always predictable and post-operative treatment may last for many weeks before full function is restored For the manual worker, when damage to both flexor tendons in a digit is complicated by lesions of the digital nerves, it may be prudent to consider early amputation

Loss of passive movement

Joint stiffness is the greatest enemy, and still the most common sequel to injuries of the hand Where there is direct damage to a joint some stiffness is

which can be spared is transplanted into the paralysed tendon or tendons, and thereby made to activate them In planning such operations it is important to use as a motor a muscle that has approximately the same excursion as the recipient tendon In complete paralysis of the finger flexors where there are no tendons available for transplantation a useful hook can be fashioned by implanting the tendons into bone with the fingers semi-flexed—so-called tenodesis

Common tendon transplants in the hand

Radial nerve paralysis—A lesion of the radial nerve proximal to the elbow joint gives rise to paralysis of the extensors of the wrist, fingers, and thumb The resultant disability can be fully corrected by tendon transplantation Pronator teres is transplanted into the short radial extensor of the wrist, flexor carpi ulnaris is used to activate the extensors of the fingers and thumb, and palmaris longus—if present—is transplanted into the long abductor of the thumb

High median nerve paralysis—A lesion of the median nerve proximal to the elbow joint results in loss of action in the long flexor of the thumb, the long flexor of the index finger and the short abductor of the thumb The middle, ring and little fingers can usually be flexed by the ulnar-innervated half of flexor digitorum profundus To restore active flexion of the thumb, the long radial extensor of the wrist is transplanted into flexor pollicis longus Flexor digitorum profundus to the ring finger is transplanted into flexor digitorum profundus to the index finger, the distal stump of flexor digitorum profundus to the ring finger being attached to the long flexor of the little finger This transplant takes no account of the thenar paralysis, but as such lesions of the median nerve usually result in impairment of sensibility in the median zone, opposition of the thumb is not a particularly important function

Thenar palsy—Paralysis of the short muscles of the thumb is frequently seen after poliomyelitis Provided there is some action in the intrinsic muscles of the index and middle fingers, so that these fingers can be opposed to the passively opposed thumb, then an opposition transplant is indicated The transplant that is most frequently used employs a sublimis tendon—usually that to the ring finger—as the motor The sublimis tendon is detached from its insertion, re-routed through a loop fashioned at the level of the pisiform and passed across the palm of the hand to be inserted into the base of the proximal phalanx of the thumb In this way the action of the short abductor of the thumb is reproduced When there are no muscles available for transplantation an opponodesis can be carried out In this operation the short extensor of the thumb is divided at its musculo-tendinous junction and re-routed across the palm of the hand to be inserted into the ulna bone On active dorsiflexion of the wrist the thumb goes into the fully opposed position

Paralysis of the first dorsal interosseous muscle—It has been pointed out above that lateral stability of the index finger is an important requisite for a pinch grip between the index finger and the thumb When the first dorsal interosseous muscle is paralysed the index finger tends to go into ulnar deviation, so that such functions as holding a pen become difficult and tiring Two tendon transplants are commonly employed for this paralysis The extensor indicis tendon is often transplanted into the tendon of the first dorsal interosseous muscle, but a more effective transplant employs the short extensor of the thumb as a motor tendon The line of action of this latter transplant is more direct

Intrinsic paralysis—When the intrinsic muscles are paralysed a typical claw-hand deformity develops This is commonly seen after lesions of the ulnar nerve, or following poliomyelitis The functional disability is due to loss of opposition of the fingers, for although the thumb can be opposed in line with the fingers, the pad of the distal phalanx cannot be approximated to that of the thumb Many transplants have been devised for

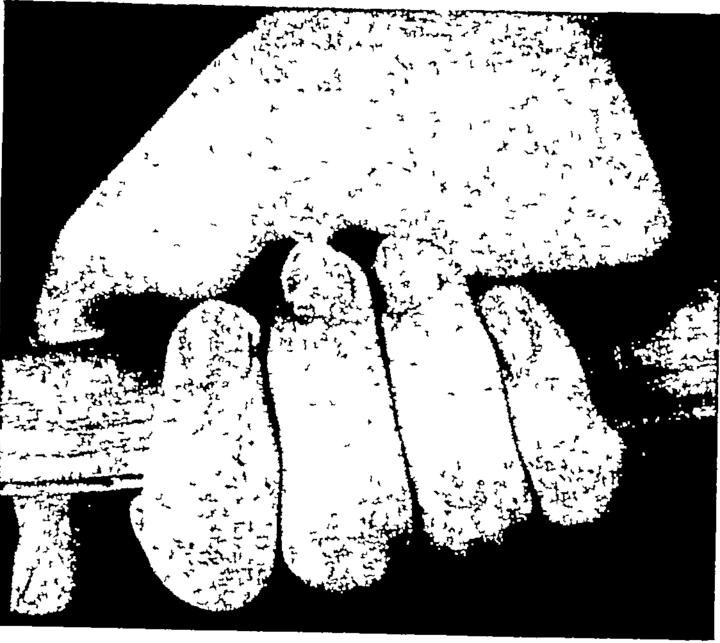


FIG 97—*Full flexion of the digits when the hand is used for gripping*

PRINCIPLES OF TREATMENT IN RELATION TO CAUSE OF DISABILITY

Loss of part of the hand

This has been considered already with reference to the function of the fingers after partial and total amputation The thumb, however, has special functions associated with its great mobility After amputation through the metacarpo-phalangeal joints there are at least two choices available (1) elongation of the first metacarpal by bone and skin grafting, or (2) deepening of the first cleft to provide a grip between the first and second metacarpals In those cases in which there is little or no thumb left pollicization of the index finger is often suggested The results of this operation vary considerably but at best it gives a hand that is cosmetically distasteful and functionally disappointing

Loss of active movement

Trauma

Extensor tendons may be divided at the back of the wrist joint, or commonly on the knuckles They are repaired by direct suture and the end-result is invariably good The prognosis in flexor tendon injuries is largely determined by the level at which they are divided Proximal to the metacarpo-phalangeal joints end-to-end suture is the rule Within the digital sheaths, however, the damaged tendon is removed and replaced by a tendon graft Palmaris longus or one of the extensors of the toes is usually used as the tendon graft The graft is secured distally to the distal phalanx of the finger and proximally it is sutured to the profundus tendon in the palm of the hand clear of the fibrous sheath In this way adhesions are less likely to occur within the finger

Paralysis

Paralysis in the hand is seen as a sequel to poliomyelitis or as a result of irrecoverable peripheral nerve injuries Restoration of function is achieved where possible by tendon transplantation In tendon transplantation a motor tendon

after operation the plaster and stitches are removed and active treatment begins It should be the aim of the physiotherapist to show the patient how the repaired tendon or tendon transplant can be made to work, and to emphasize that the rapidity of recovery and, to a great extent, the degree of recovery must depend upon the efforts of the patient himself The hand should be warmed before each treatment Scars are mobilized by oil massage, particularly when they overlie a tendon A careful note of the range of joint movements should be kept so that progress can be recorded accurately

Provided improvement is steady, its slow rate need not cause alarm Tendon grafts, for example, rarely reach their final grade of recovery until some 9 months have elapsed from the time of operation Clearly, physiotherapy is unnecessary during the whole of this long period As soon as the patient has learned the exercises and can carry them out effectively on his own he should be encouraged to return to his job There is no doubt that repeated unconscious movements are more effective in promoting recovery than monotonous active exercises unrelated to normal function In the early stages remedial occupational therapy can be of great value in establishing automatic function of the hand

Tendon grafts

The aim is to restore gliding movement of the tendon graft throughout the whole length of the affected digit This is achieved by isotonic and isometric contractions In most digital tendon grafts the proximal stump is sutured to its original profundus tendon As the profundus tendon merges into a common profundus muscle, so active movements of the affected finger can be encouraged by mass flexion of all the fingers The metacarpo-phalangeal joint is stabilized by the physiotherapist and active contractions of the proximal interphalangeal joint are carried out This is followed by fixation of the metacarpo-phalangeal and proximal interphalangeal joints so that active flexion is canalized to the distal interphalangeal joint The patient can be taught to carry out these movements by using a matchbox to stabilize each joint in turn (Fig 98) Equally valuable are isometric contractions, these are carried out by asking the patient to exert strong pressure between the opposed thumb and the affected digit as, for example, in using a needle for sewing, or pulling heavy twine in making a stool seat (Fig 99)

Treatment should be carried out daily until about 25 per cent of the full range of active flexion is regained At this stage it is wise to discontinue physiotherapy and to rely on the activities of the patient himself in his work to regain the full range of movement

Tendon sutures

The same principles of treatment apply to flexor tendon injuries at the wrist joint and in the palm of the hand, where direct tendon repair has been possible A Capener type of knuckle-duster splint can often be effectively employed to control the metacarpo-phalangeal joints and so canalize active movements to the interphalangeal joints during the early stages of treatment In this way the natural tendency for all movement to take place at the metacarpo-phalangeal joints is discouraged

Tendon transplants

After tendon transplantation there are two problems (1) to re-educate the

this deformity but the commonest one employs flexor digitorum sublimis as the motor tendon The sublimis tendon is detached from its insertion, withdrawn in the palm, and re-routed through the lumbrical canals to be inserted into the extensor apponeurosis In this way the stabilizing action of the intrinsic muscles on the metacarpo-phalangeal joint is restored

Loss of passive movement

Loss of passive movement in the metacarpo-phalangeal and interphalangeal joints of the hand is a very serious disability It occurs commonly either as a result of continuous splinting in one position, or as a sequel to oedema, rarely is it seen as a result of direct joint injury Physiotherapy in the form of frequent passive movements is more successful in preventing than alleviating joint stiffness Stiffness in the metacarpo-phalangeal and the interphalangeal joints is primarily due to contracture of the lateral ligaments These ligaments by reason of their mode of insertion are shortest when the metacarpo-phalangeal and interphalangeal joints are extended

The operative correction for such stiffness is excision of the lateral ligaments. While this will often succeed in restoring the full range of flexion, considerable lateral instability of the joints may result Surgical measures for restoring mobility to the interphalangeal joints are disappointing, and if a joint has a limited, painful range of movement then fusion in the optimum position is often the wisest plan

An adductor contracture of the thumb commonly follows long-standing paralysis of the thenar muscles and frequently has three components· (1) the capsule of the metacarpo-phalangeal joint, (2) the adductor pollicis muscles, and (3) occasionally the skin of the first web space The contracture, however, is amenable to surgery and when the structures inserted into the inner side of the first metacarpal are stripped and the capsule of the carpo-metacarpal joint excised, then a full range of passive opposition of the thumb is often possible This operation may precede tendon transplantation for opposition of the thumb

Impairment of sensibility

There are two methods of dealing with this problem If possible, nerve repair is used to restore at least protective sensibility. For those patients who depend for their livelihood on normal sensibility in the median nerve distribution, there is much to be said in favour of transplantation of normal skin from an adjacent area, keeping the blood and nerve supply intact. For example, the skin on the dorsum of the thumb can be swung round to the volar aspect of the thumb in a median nerve lesion

PHYSICAL TREATMENT AFTER RECONSTRUCTIVE SURGERY

General principles

After all surgery the hand is elevated for at least 5 days A roller towel is used to take the weight of the limb under the elbow and upper arm In this way oedema is prevented and joint stiffness avoided Following tendon suture, tendon grafting and tendon transplantation, active movements are deferred for 3 weeks in order to allow sound union to occur If movements are begun too early there is a risk that the tendon junction may rupture, as for the first 3 weeks continuity depends upon the strength and adequacy of the suture material alone Furthermore, an oedematous reaction may be provoked causing adhesions to form Three weeks

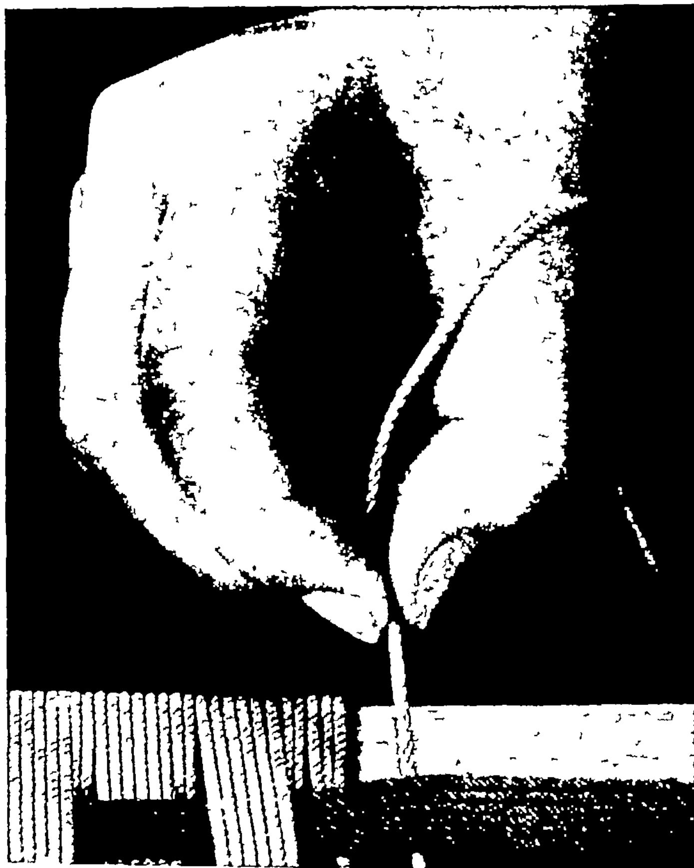


FIG 99 —*Isometric contraction of the index finger after tendon graft*

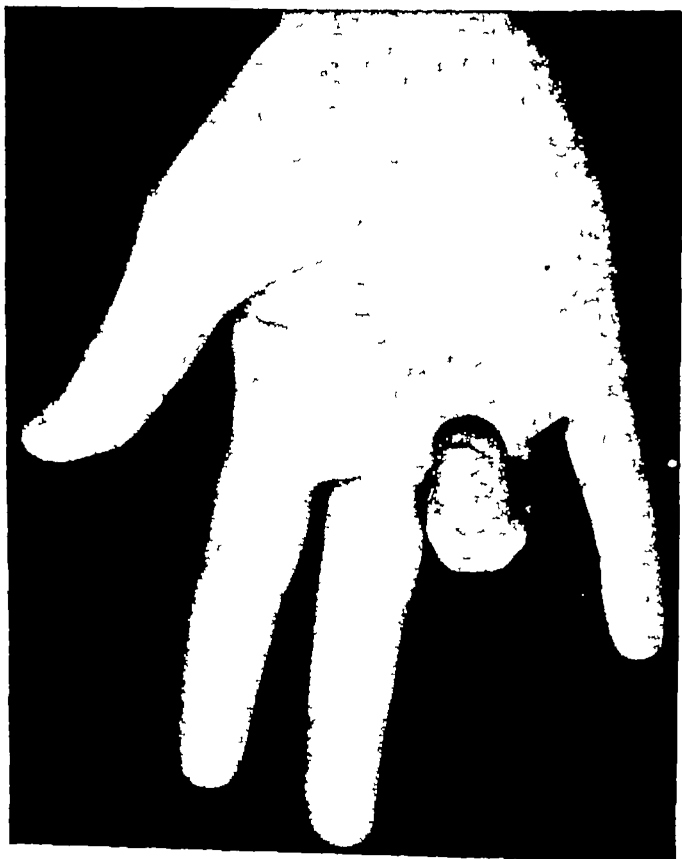
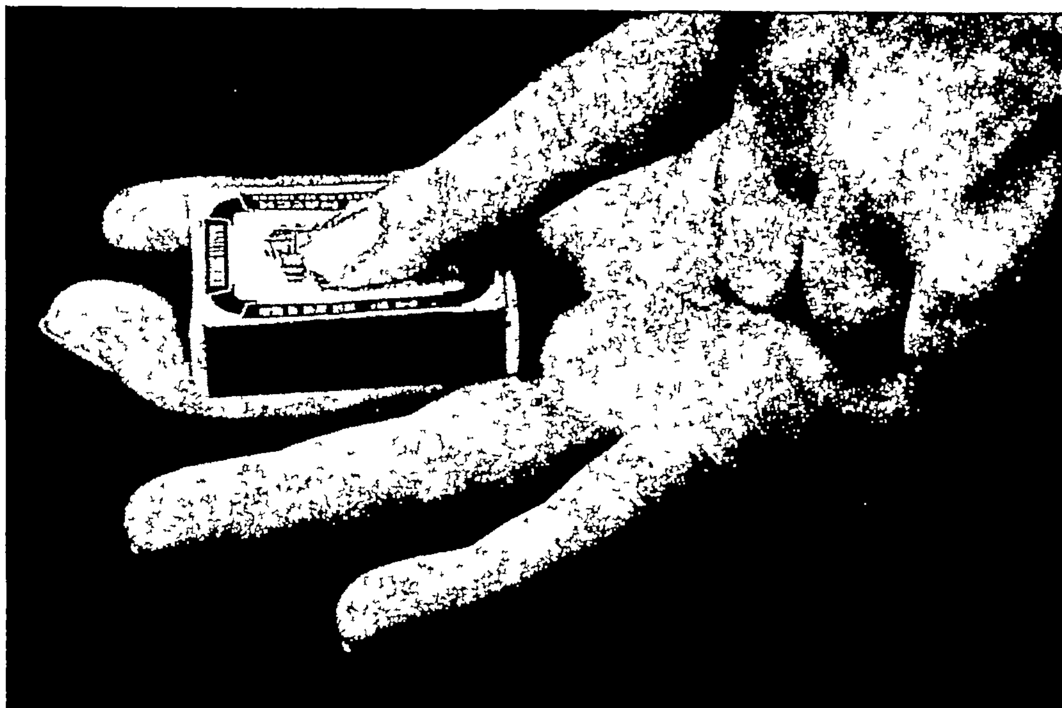


FIG 100 —*Isolation of sublimis tendon to the ring finger*



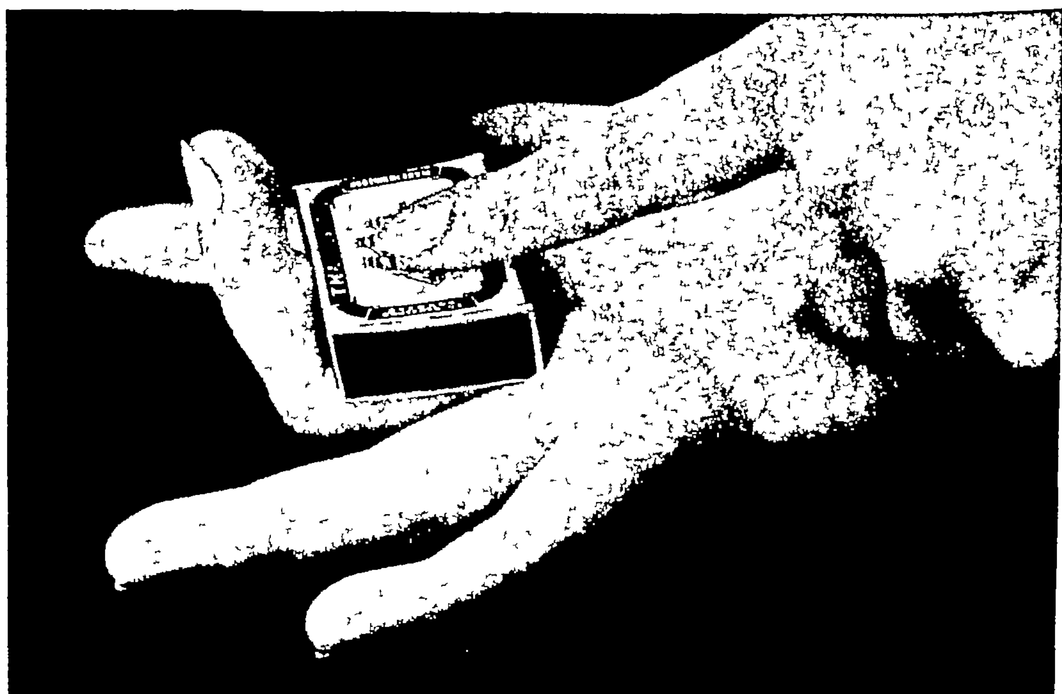


FIG 98 —*A matchbox being used to stabilize the metacarpo-phalangeal and interphalangeal joints during re-education of a tendon graft*

transplanted tendon, and (2) to regain a full range of movement It is a great help if isolated movements of the donor tendon can be practised before operation For example, a patient can be taught to isolate the sublimis tendon to a given finger with ease (Fig 100) so that after the tendon has been transplanted re-education is considerably simplified

attempt to flex the ring finger at the proximal interphalangeal joint. The transplanted sublimis tendon of the ring finger will then cause the thumb to go into palmar abduction. Later, when this movement can be carried out against resistance, opposition of the thumb to each finger is allowed. If opposition is not deferred until the movement of palmar abduction has been completely re-educated a slow deterioration will occur. The patient must master the essential movement in opposition of the thumb, namely, full palmar abduction, without which rotation of the first metacarpal at the carpo-metacarpal joint cannot occur. Physiotherapy is usually continued for a period of about 4 weeks.

Intrinsic paralysis

The same principles apply to the re-education of these transplants as have been pointed out already; namely, complete re-education of the transplanted muscles must be achieved before normal use of the hand is allowed. If this step is neglected then it is possible that the old pattern of movement will be re-established and the transplant will fall into disuse.

(All illustrations in this chapter appear by kind permission of the Institute of Orthopaedics.)

Radial nerve paralysis

The re-education after tendon transplantation is not difficult The extensors of the fingers and thumb are activated by flexor carpi ulnaris, a muscle that normally contracts to stabilize the wrist joint on active extension of the fingers Thus, on attempted extension of the fingers after tendon transplantation the muscle will usually contract In order to avoid a tenodesis effect it is wise to start by stabilizing the wrist manually so that active extension of the fingers at the metacarpo-phalangeal joints may be practised (Fig 101) In this way mobility of the tendon



FIG. 101.—*Stabilizing the wrist during re-education of a radial tendon transplant*

junction in the soft tissues is quickly gained In some instances, electrical stimulation of the belly of flexor carpi ulnaris is helpful, both for re-education and mobilization of the transplant

Active dorsiflexion of the wrist is taught by asking the patient to pronate the forearm and at the same time to think about extending the wrist. A plaster cock-up splint should be retained between treatments for the first week to remove any tension from the pronator teres transplant As soon as the wrist can be actively dorsiflexed unaided the splint is discarded.

Oil massage to all scars is a valuable aid to dispersing adhesions. Daily physiotherapy is continued for a total period of about 3 weeks.

Thenar paralysis

Three weeks after operation, when the plaster and stitches are removed, a small plaster wedge is fashioned to maintain the thumb in full opposition between treatments It is most important in the re-education of this transplant that opposition of the thumb to the fingers should not be encouraged until powerful palmar abduction has been regained The most useful method of re-education is to stabilize the index, middle and little fingers in full extension and then to ask the patient to

attempt to flex the ring finger at the proximal interphalangeal joint The transplanted sublimis tendon of the ring finger will then cause the thumb to go into palmar abduction Later, when this movement can be carried out against resistance, opposition of the thumb to each finger is allowed If opposition is not deferred until the movement of palmar abduction has been completely re-educated a slow deterioration will occur The patient must master the essential movement in opposition of the thumb, namely, full palmar abduction, without which rotation of the first metacarpal at the carpo-metacarpal joint cannot occur Physiotherapy is usually continued for a period of about 4 weeks

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(All illustrations in this chapter appear by kind permission of the Institute of Orthopaedics)

CHAPTER 10

RESETTLEMENT

THIS chapter deals with the resettlement of patients with severe loss of function It is an important part of medical treatment to ensure that the patient who, because of extensive loss of function, cannot return to his old job is found new work adequate to his abilities

The Piercy Report of 1956, paragraph 42, stated that consultants and general practitioners are still slow to consider the rehabilitation needs of their patients, and that they still require education in the scope, nature and potentialities of rehabilitation

Since the end of World War II, a great deal has been done for the needs of the disabled person Anyone reviewing the varied nature of the services available will realize that it is not more money or more services that are now required, but a better knowledge of their existence and a more efficient use of them

All disabled people require the best possible advice and facilities for satisfactory resettlement, and in none is this more important than in the patient with a severely affected hand

In the first part of this chapter the various services, both national and voluntary, will be reviewed in detail and the type of resettlement clinic that has proved to be successful in practice will be discussed In the second part of the chapter, specific problems in the resettlement of those with hand injuries will be analysed

NATIONAL FACILITIES

In 1944 the Disabled Persons' Employment Act was passed, being the first big step in providing facilities for disabled persons Two years later the National Health Service was introduced, and in 1948 the National Assistance Act made provision for the welfare of handicapped persons, thus the employment, the treatment, and welfare needs of disabled persons were all catered for in considerable detail within a period of 3 years of the end of World War II

Disablement Resettlement Officer

The main backbone of the service for the disabled is the Disablement Resettlement Officer (D R O) Recruited from the Ministry of Labour staff, his statutory duties are to advise the disabled on employment problems, and to make liaison with employers for the satisfactory employment of disabled people A register of disabled persons is kept at every Labour Exchange, and it is essential that a disabled person should be registered before he can obtain all the available facilities At present there are some 500,000 people on the register

The definition of a disabled person is one who through injury or disease is substantially handicapped in obtaining employment Normally, medical evidence is required before the D R O can register a patient as a disabled person When the hospital consultant refers a patient, this evidence is given on form D P (1), which is in no sense a medical history but a method of estimating the patient's abilities

and handicaps with an indication of the prognosis of the condition When the patient's own doctor refers him to the D R O the evidence is given on Form D P (32)

If the disablement is obvious, for example, loss of a limb, medical evidence need not be sought

Once registered, the patient is given a green card which he can present at any Labour Exchange in Great Britain and be sure of receiving the advice and help of the D R O

Apart from his work at the Labour Exchange advising patients who come to him and making liaison with employers, he has a statutory duty to visit hospitals and medical institutions where there are patients requiring his advice The frequency of visits is arranged between the D R O and the appropriate institutions In some hospitals there is a regular resettlement clinic which will be described in detail later In some, the D R O visits only when needed, in too many he is not invited to visit at all

Initially, patients are put on the register for a period of 1–5 years Two months before the end of this period the patient is reviewed by the D R O who will decide whether he should remain on the register In case of doubt, the problem is referred to the Disablement Advisory Panel

There are various ways in which the D R O can help the patient to get employment Whenever possible he visits local industries in order to maintain an up-to-date knowledge of the type of work available and, of course, the vacancies that exist By an Act of Parliament, those employing more than 20 work people must have a " quota " of their employees as registered disabled persons The present figure, which the Minister can alter, is 3 It is an offence for an employer to engage able-bodied workers if his disabled quota is not up to strength However, this system does not cater for the majority of disabled persons

It is wise, if possible, to resettle the patient into the same sort of job he was doing before his disability, but if this is impossible there may well be many different jobs that he can do in the same firm Close liaison between the D R O and the Personnel Management Staff will result in satisfactory placing Obviously the more intimate rapport that exists between the D R O and the employers, the easier it should be to resettle a patient This takes time and it means that the D R O has to be away from his office, but experience has shown that this is by far the best way of getting results

There is room for considerable research into the type of jobs that can be done by disabled persons, and there is a need, too, for an intermediary between the medical staff looking after the patient, and the employers, who can advise on suitable work positions, alteration of machinery, rest periods, and so on This job will normally be done in large firms by the Industrial Medical Officer, but his job is often difficult as there is room for better appreciation of the problems of the disabled person in industry This problem will be discussed later in greater detail

Government training scheme

If a patient requires resettlement in a new trade, the Government training scheme is used There are now 16 Government training centres in Great Britain, providing training in a wide range of different trades specifically for the disabled person

When a patient requires training in a subject not covered by the scheme, arrangements can be made with outside organizations or with individual employers. In such cases the State will finance the organization or employer direct The Government training centres are situated in the following areas

London	Enfield Kidbrook Perivale Waddon	East and West Ridings	Hull Leeds Sheffield
		North-west	Liverpool Manchester
East	Letchworth		
North	Felling-on-Tyne	South-west	Bristol
Midlands	Birmingham Coventry	South	Slough
		Wales	Cardiff
North Midlands	Leicester Long Eaton	Scotland	Edinburgh Glasgow

The courses are usually for 6 months, though some, particularly watch and clock repairing, are for 1 year The list of trades taught is too large to reproduce here, but it includes all sections of the building trade, engineering, draughtsmanship, fitting, welding, boot and shoe making and repairing, electrical servicing, motor repair, radio and television servicing, display painting, surgical appliance making and watch and clock repairing Application for enrolment at one of these centres is made by the D R O when the patient has been registered as disabled

For most courses, a test and an interview is required before acceptance In draughtsmanship, for example, a test involving algebra and simple trigonometry is given and the patient's industrial background reviewed by a committee The object of this interview is to ensure that only those who have a sound chance of completing the course and being successful tradesmen are accepted as trainees

Apart from the financial aspects of wasted training, if a disabled person fails at the end of a course, it is liable to have a severe psychological effect on him and may make his future employment extremely difficult

There are both residential centres and non-residential centres, if a patient wishes to attend a non-residential centre but lives too far away for daily travel, the D R O will help him to obtain accommodation

The training is free and patients receive certain allowances An unmarried trainee aged 20 years or over receives 90s a week A trainee with a wife, and children under the age of 16 years, receives 118s a week A lodging allowance is payable for those living in lodgings, and a travel allowance is available In cases of real hardship, a grant may also be allowed from the National Assistance Board to supplement the essential financial requirements of the household

On completion of the course, the patient is considered to be a semi-skilled person, he is then offered a position in the appropriate industry as near to his home as possible The placing of trainees is the responsibility of the D R O , and it must be emphasized that there is no direction of labour The patient is free to refuse jobs if he wishes, within reason

A trainee does not receive full union rates of pay during the first 18 months of employment as he is not considered to be a fully skilled person

During training regular tests are held to assess the patient's progress and to prevent those who are obviously not going to complete the course from wasting further time

The patients work hard at these centres, the hours are those of a full working day, and the standard of training is extremely high

Only in special cases is medical treatment provided, though all are under the observation of the medical officer throughout training

There is a gymnasium attached to Queen Elizabeth's Training College and a remedial gymnast is in attendance

It is possible, in exceptional cases, to allow a patient daily treatment, but his course is then extended by 3 months or more In the main, these centres are designed for patients who have reached medical or surgical finality

Of the disabled patients invalided from the Royal Air Force rehabilitation centres during the last 6 years, about one-third have been trained at one or other of the centres This high figure is to be expected most among the younger age-groups, and many, of course, have not received any training before joining the Service In the type of patient seen in civil hospitals, the figure is much lower

Wherever possible the patient is encouraged to return to his previous employment, or to a modification of it, re-training is indicated only where absolutely necessary Finance is one of the major obstacles to a patient taking up re-training

Although payment of allowances is made during training, many patients cannot afford to meet their various financial commitments, among which, these days, are hire-purchase repayments, this is a difficult problem Very special effort is made to persuade young people to forego easy money immediately and take the long-term view by becoming skilled tradesmen It is a great temptation for a young person to engage in many types of unskilled labour as the immediate wage is high The prospects however, of such employment are never as good as for a skilled man, furthermore, the best resettlement for a disabled person is into the most skilled job that he can perform Not only will this give satisfaction and enable him to conquer the disability, but the more highly skilled the less likely he is to lose the job in times of economic stress

Before applying for enrolment at a Government training centre, care should be taken to ensure that there are adequate openings in the particular trade in which the patient is being trained near his home It is usually impossible, due to the housing shortage, for him to move to any district where the appropriate work is available The patient usually chooses a trade in which he can find employment near his own home

Designated employment scheme

There are two occupations which are open only to registered disabled persons, these are car park attendant and passenger lift operator It is not the Government's intention to increase the number of occupations under this scheme

Industrial rehabilitation units

There are at present 13 industrial rehabilitation units, and they are situated in industrial areas at Waddon, Felling-on-Tyne, Birmingham, Coventry, Leicester, Long Eaton, Hull, Leeds, Bristol, Egham, Cardiff, Edinburgh, and Hillington, Glasgow Their function is to assess a patient's capabilities for employment and, by an intensive course of work, to restore confidence and prepare him for the rigours of industrial life after long spells in hospital

The maximum time that is spent in these industrial rehabilitation units is 12 weeks, most patients spend 8 weeks there There is room for 200 at Egham, which is the only residential unit, and 100 at each of the others

The staff of a rehabilitation unit comprises a doctor, a vocational worker, a social worker, a D.R O , and a chief occupational supervisor. Patients are under the control of a rehabilitation officer who is not a doctor.

A wide range of machines and tools are provided in all types of activity

Functional and educational assessment and psychological testing are aimed to help the patient decide on the trade appropriate to his abilities Many patients will therefore go on to a Government training centre from the industrial rehabilitation unit The activites are graded so that the atmosphere of a modern industrial factory is gradually created

There are woodwork, assembly, and engineering sections The work is all productive and patients receive a weekly payment similar to those in Government training centres A remedial gymnast is in attendance and there is a close liaison between the unit medical officer and local physical medicine consultant The unit medical officer must have had previous experience of industrial medicine before appointment

There is, of course, a hard core of difficult patients at such units and this accounts for the fact that on a recent analysis of 500 persons admitted to a particular industrial rehabilitation unit, 20 7 per cent were unplaced when they left the unit However, 63 8 per cent were found employment and 15 5 per cent were transferred to a Government training centre There is no doubt that these centres serve a most useful purpose, as will be indicated later

It is felt, however, that many more patients could be assessed and helped to an early return to work by graduated activity through better use of the rehabilitation facilities in hospitals than by sending them to industrial rehabilitation units Furthermore, some of the difficult problems are not solved by the transfer of a patient to a different doctor who has not had the experience of this particular patient and his personal reactions to the disability

Sheltered workshops

Sheltered workshops have been opened for the very seriously disabled patients who cannot earn their living in open competitive industry, and further workshops under an organization known as Remploy have been opened up where such patients can work at a slower rate These workshops are especially useful for such diseases as epilepsy, organic nervous diseases, respiratory tuberculosis and muscular dystrophy Selected cases of recovery from psychiatric breakdown also do well Each employee is reviewed medically at least once every 6 months

Remploy is a public company, receiving Government loans to cover expenditure It operates at a loss which is met through public funds There are 90 factories in Government buildings at present employing 6,000 severely disabled persons As it is essential that there should be some reasonably able-bodied persons to fill some of the posts in the factories, a campaign is organized to recruit some 15 per cent of this staff from the less severely disabled The work undertaken includes book binding, leather work, the manufacture of cardboard boxes, furniture, surgical appliances, and so on Minimum rates of pay are 3s 2½d per hour for a 44 hour week in the London area after 2 years' service, increased pay is given for higher efficiency

Industrial rehabilitation units can be used to assess the suitability of all patients for Remploy Each year some 250 Remploy workers leave the factories to take up

work in outside industry Although the scheme operates at a loss and, as the Piercy Committee pointed out, it is unreasonable to expect such a scheme to operate without a loss, the humanitarian aspect is outstanding Even from the economic point of view it is better for severely disabled patients to be able to make some contribution towards production rather than none at all

Sheltered workshops also exist at the 2 voluntary training centres Queen Elizabeth's Training College, at Leatherhead, and St Loye's, at Exeter

For the severely disabled patients confined to their home, provision is made for tuition in crafts such as leather work and basket work under the National Assistance Act, and this is under the charge of a local authority Patients are allowed to earn up to £1 per week without deductions from their state grants

Professional grants

Under a special education and training scheme, grants were available to ex-servicemen who wished to take up a professional training This scheme has now lapsed and applies only to disabled patients

When a patient cannot be satisfactorily placed in employment by the D R O , either directly through the Employment Exchange or through the Government training scheme, a grant of money is payable in special cases for patients to take up professional training The patient must show evidence that he intended to continue his vocation before disability Grants are made by the Ministry of Education and full fees for training and maintenance can be claimed Under this scheme patients have been trained as school teachers and have taken courses at many of the universities Two of our patients with hand disabilities made use of this scheme, one trained to be a school teacher and the other as a geologist at a university

If a patient can show that it is impossible for him to work with other people, a grant may be made for the setting up of his own business, for example, one patient has had a workshop built in his garden, fully equipped, to enable him to repair boots and shoes These grants can be substantial in amount Under Section 29 of the National Assistance Act, 1948, local authorities may make provision for structural adaptations, such as the widening of doors, raised toilet seats, and so on Full use should be made of these facilities

Disablement advisory committees

These committees exist to advise the Ministry of Labour on a local basis There are some 300 committees attached to main Employment Exchanges They consist of an independent chairman, who is usually a person of some local standing, an equal number of employers, and workers' representatives, and other persons chosen for their knowledge of the problems of the disabled, some of whom are members of voluntary organizations and welfare societies There is also a medical member, nominated by the Ministry of Labour, who is banned from acting as a medical member of a panel

The committees advise on problems in the areas and make recommendations to the Minister of Labour Other executive functions are to recommend on specific matters connected with the registration of disabled persons and any other matters that may arise in the area A committee sometimes appoints a panel, the members of which need not necessarily be members of the full committee Usually it consists of an independent chairman, employers' and workers' representatives, a

doctor, and a person with experience of problems of disabled persons Both these organizations serve a useful function but are not widely enough known, it is certain that their services can be better used

Integration of facilities

Patients who require special transport facilities can be provided, through the Ministry of Transport, with invalid carriages This is arranged through the D R O It is often necessary for a patient to have an invalid carriage before he can take up a training course However, enrolment on a training course is made conditional on the possession of such transport, whilst in turn the carriage will not be provided until the patient has been allocated a place on the course This situation has been known to arise on a number of occasions

One of the criticisms of the present scheme for the disabled is that too many organizations are concerned with the disabled person, and there is not enough liaison It has been suggested that there should be a ministry set up to deal with all the problems of the disabled, but this was not accepted by the Piercy Committee, who recommended that better liaison between the various persons concerned with the disabled would solve the problems

One fact has emerged quite clearly in our experience in resettlement—a closer relationship between the D R O and the doctor solves almost all the problems that are likely to arise For this reason it is felt that the resettlement clinic is the best place to tackle the problems, it is here that the doctor and the D R O can come to close liaison on any given case so that in time the doctor learns a good deal about industrial employment, and the D R O improves his knowledge on the medical problems of the disabled

At the industrial rehabilitation unit at Waddon, where there are specially difficult placement problems, the D R O of the patient's local Employment Exchange is asked to sit in at the final conference so that he can be given a complete picture of the patient's aptitudes and disabilities as seen by each member of the team

Resettlement clinics

Special clinics have been organized in some hospitals and rehabilitation centres to deal with all the problems confronting the disabled person During the last 7 years we have operated such a clinic at our Centre, and we are convinced that this is the ideal way to cope with the resettlement of the disabled The clinic meets as often as necessary, and not less than once a week The members are the patient, the doctor in charge, the D R O , an almoner or appropriate equivalent (welfare officer in the Services), an occupational therapist, and anyone else who may be able to give advice in a particular problem A full industrial and social history is compiled which includes any problems associated with accommodation, finance, transport, education, and so on, for discussion before the patient is brought to the clinic

At the clinic the doctor presents a brief outline of the medical history, including the prognosis, the occupational therapist gives her observations, on the patient's abilities, his reaction to work and the ability to handle tools (*see* Chapter 8), the almoner or welfare officer discusses any social or domestic problems that may arise The D R O will then advise the patient on training facilities, employment prospects, or take steps to find out about such matters for discussion at the next

meeting at the clinic The object of the first attendance is to show the patient all the various facilities that exist for his resettlement, and to give him confidence and encouragement It is beneficial to introduce the patient to the clinic at an early stage of rehabilitation, even though he may not be taking up employment for many months It is essential that the patient should be assured that everything possible will be done to find him satisfactory work, or that he will be re-trained in a new trade, he can then participate in all the rehabilitation activities with a calm mind

As soon as a patient has decided on one or perhaps a number of trades, the next step is to give him a trial period of work It is an advantage if the patient can be given the opportunity of trying out a chosen trade for himself

The following three questions require to be answered in such circumstances

(1) Is the patient physically fit for the job? The only way to ascertain this is for the patient to try out the job for himself

(2) Does the patient like the job ? Patients may be attracted to a particular job for a variety of reasons They may well change their minds when they actually get down to the job itself We have found that some patients, in theory, feel that they would like to take up watch repair, for example, but they soon find that the close attention to detail and the endless patience required does not suit their temperaments Some, on the other hand, are in error as to the nature of the work One patient was emphatic in his desire to be a draughtsman but quickly changed his mind when he discovered that the job was not drawing beer in a public house.

(3) Does the instructor or supervisor feel that the patient is likely to make a success of the job ?

Once these questions are answered, a patient can confidently be advised to take up the employment chosen, with or without training as the case may be Sometimes, it requires only an afternoon or a day to solve these problems, but in other cases it may take much longer

We have been fortunate at our Centre in establishing a close liaison with a nearby Government training centre who allow us the facilities to have patients tested at their chosen trades When possible it is eminently desirable that patients should combine part-time re-training and rehabilitation, this gives the patient a goal to work for which lessens the time in which he will be out of work It will be seen that this scheme dispenses with the necessity of sending the patient to an industrial rehabilitation centre in all but the most difficult cases

This is in no sense meant to be a criticism of these centres, but it is obvious that the sooner a patient's future is decided, the better, and by making use of the occupational therapy department, their workshop facilities, or the rehabilitation centre, a great deal can be done to help the patient decide on his future

Where such facilities are not available, or when the patient's problems cannot readily be solved in this way, the industrial rehabilitation units are very often ready to offer their advice by interviewing and assessing patients for one or two days It is often not necessary to have to admit a patient for the full course at such a unit, a day or two may be all that is necessary Certainly, on this basis, the industrial rehabilitation units should be used more by the resettlement clinics for assessment of a patient's abilities

The atmosphere of the resettlement clinic is very important The patient should be encouraged to talk freely, explain his problems, and it must always be

remembered that what is obviously straightforward to the doctor and the staff may be very different to the patient

Several attendances at the clinic are recommended throughout the period of treatment Each attendance may be for only a few minutes, merely for the D R O to convince the patient that he is actively engaged in arrangements for his future, or in discovering additional useful information, and this may be very important to a patient who is naturally worried about what is going to happen

The ability to talk about his problems and to receive the advice and opinions of a number of people with different points of view is of tremendous help to the patient in making up his mind Time spent at these clinics is never wasted for it may prevent a patient from taking up the wrong sort of employment, or from drifting into unskilled labour with all the serious implications for his disability that this holds

Glanville (1956) described his resettlement organization It does not differ in principle from the conventional type, but he has arranged for a disablement resettlement officer to be seconded from the Ministry of Labour to his rehabilitation unit This officer has contact with employers throughout the whole of his area and spends a certain proportion of his time visiting these employers and learning about the various jobs available Furthermore, he is able to translate the functional potential of the patient into work on the factory floor Clearly, this is a considerable advance in resettlement, and there is undoubtedly a place for this type of person as an essential member of the rehabilitation team

In many cases an employer may have to be persuaded that a disabled person is perfectly able to carry out a full day's work, provided the right type of work is chosen for his disability This needs patient explanation and personal contact It has been found that once an employer has placed a disabled person in the right sort of employment, that worker gives such loyal and conscientious service that the employer is anxious to have more disabled people on his staff

The organization of the resettlement clinic is devised so that the ultimate person in charge is the doctor Any resettlement organization that is not so constituted is liable to fail in the last resort because only a doctor can appreciate the possible fluctuation of a disability (such as rheumatoid arthritis) and assess the ways in which employment may affect the patient and his condition

In a rehabilitation centre, facilities usually exist for deciding on the sort of employment most suited to a patient's disability and the machinery of the clinic will indicate at the earliest possible stage the likelihood of employment in the patient's home area, or the training facilities available In really difficult cases, such as extensive loss of function in the hands, it may take months to discover the right type of job for that patient Consequently, the sooner the patient is brought before the clinic, the better

There are certain general principles which are at the basis of all satisfactory resettlement First, the patient must understand his disability This means that the doctor should take great care to explain in simple language the exact nature of the condition and the prognosis This should include advice on the sort of conditions to be avoided, for example, extremes of heat and cold He should be warned of any sensory loss in the hand and given advice on the precautions to be taken in cold weather, and in such matters as moving machinery

Secondly, the patient should be encouraged to make the most use of his abilities

Those who have experience of the severely disabled know just how much potential waiting to be realized there is in most people This is particularly true in patients with poliomyelitis Perhaps the most dramatic of all patients we have seen was one who was paralysed below the neck, but despite this learnt to paint with a brush between his teeth and is now earning his living by this means The aim should be for the patient to be in a more skilled occupation than before his disability

Thirdly, resettlement should be started as early as possible during treatment, and the various aspects such as vocational guidance, re-training, provision of gadgets for work, self-help devices and invalid transport should be dovetailed to cover the least period of time Much can be done by using the existing facilities of an ordinary hospital and adapting these to specific requirements

Fourthly, there should always be personal contact between the doctor and the D R O The filling up of forms is never a substitute for discussion together in the Clinic At present the D R O s do not have a skilled course of training in the problems of the disabled person The Piercy Report has commented on the lack of such training, and it is therefore even more important that every opportunity should be given to the D R O to become familiar with the doctor's point of view It is likely that job analysis and time and motion study will become increasingly important, and at least one member of the Clinic, either the D R O , or the occupational therapist, will have to regard this as part of their responsibilities

Compensation problems

O'Malley at a meeting at the Royal Society of Medicine in 1957 stated that 15 per cent of patients in a civil rehabilitation centre are compensation cases He compared the treatment times in a group of compensation cases and non-compensation cases The total treatment time was just double for the compensation cases, the great majority of this increased time was spent at the hospital

The problem of a patient awaiting settlement of a compensation claim is a very real one, and while a complete solution cannot be offered here, certain aspects of the problem must be discussed

In 1948 new legislation on compensation laid down that an injured worker could claim in two ways for the consequence of his injury First, the National Insurance and Industrial Injuries Act provides payment for the degree of disablement The Act is administered by the Ministry of Pensions and National Insurance, quite distinct from the Law Courts In cases of dispute, the workman has a right of appeal to the Local Appeal Tribunal, consisting of a chairman and two other members, one the trades union representative, and one the representative of the employers' organization

A married man with one child is entitled to £5 4s 0d a week A special hardship allowance is payable up to a maximum of 27s 6d a week for loss of earnings, in such conditions as when the patient has had to change his regular occupation

This Act replaced the old Workman's Compensation Act, removing the unfair bias that existed whereby a skilled man with a mild injury might be worse off than an unskilled man with a severe injury

Secondly, an injured workman can claim for damages at Common Law

Before 1948 it was not possible to claim for both Now, irrespective of whether

the injured person is claiming in the Courts or not, he receives his National Assistance. The claimant has to satisfy the Court that someone was to blame for the injury Damages are awarded as a lump sum to compensate the patient for loss of wages, expenses, pain and suffering, and possible disability in the future

If a patient is a member of a trade union, the legal department will deal with the claim, otherwise this is done through a private solicitor

Before the claim is settled, a long time elapses during which various medical examinations are made, reports are taken by the insurance company and employers, offers may be made and rejected,and the patient becomes possessed more often than not of a compensation neurosis, on the one hand he is being persuaded to return to work by his wife, and he himself finds that he is losing money by being unemployed, on the other hand there may be pressure from the trade union to go on with the case lest it creates a precedent by a less adequate settlement than he deserves It is true to say that the aim of the injured man's advisers is to get him as much money as possible and conflicts with the aim of the defending insurance company to minimize the damages This means that a long time elapses between injury and eventual settlement

Medical advice is invariably in favour of an early settlement, and O'Malley has suggested that a round table conference between all interested parties should be called in the early stages so that the most can be done for the patient in getting him back to work as soon as possible Whereas the majority of workmen return to work as soon as they are fit, there is a significant minority who do not do so in the hope of obtaining a substantial sum of money. If the greatest amount of money is to be awarded in damages, it is difficult for the patient not to get into the habit of making the most of his disability There is a widespread belief among the workers that a return to work before the claim is settled may reduce the amount of damages awarded

The real core to this problem lies in the attitude of the injured man and the relations between him and his employers If the patient can be made to realize how important it is that his rehabilitation should be started as early as possible, and if the employer has a reputation for fair dealing, difficulties arise much less frequently

Even when a substantial settlement is made, the money may well not be used for the purpose for which it was granted A recent review of over 300 cases of compensation showed that only 18 per cent used the money to set up a business and in 50 per cent of these the business failed It was estimated that in nearly 90 per cent of another series of over 100 cases followed up, the money did not go towards resettlement at all

In the last resort, the difficulties of compensation problems will be substantially overcome if there is a closer understanding between all the interested parties, and a realization that all concerned should have as their main goal the speedy rehabilitation of the patient and his return to work Consequently, the doctor has a vital part to play in representing to both sides the importance of these points

The best way to avoid, or at least minimize, compensation neurosis is to provide a background of interest in getting the patient back to work, and it may well be that all the resources of a rehabilitation department will have to be used to

encourage the patient to forget his disability and to work to regain function as quickly as possible

It has been suggested that if liability was admitted in the early stages of litigation and the question of the amount of damages left for subsequent negotiations, this would go a long way towards solving the problems

Above all, it is vital that the patient should not be encouraged to spend a period of inactivity unless it is absolutely necessary, and the doctor can do a great deal to persuade the patient to return to work if he takes the trouble to explain the possible complications and limitations that may arise in the future

VOLUNTARY ORGANIZATIONS

There are an enormous number of voluntary organizations which help disabled persons in a variety of ways Some are concerned with specific disabilities such as deafness, blindness, loss of limbs, spasticity, infantile paralysis, and many others A full list of these organizations with their addresses and their particular functions is included in a book by the Ministry of Labour and National Service (1955)

It is very important that all persons connected with the resettlement of the disabled should be fully aware of the various societies and organizations—both national and voluntary—that exist to help the disabled person There are practically no patients whose problems are so difficult that one or another of the organizations cannot materially help

SPECIFIC RESETTLEMENT OF PATIENTS WITH HAND DISABILITIES

General remarks

As each patient presents a different problem, and the resettlement of a particular patient depends on so many other factors besides his physical disability, only a general indication of resettlement can be given here

The aim of rehabilitation of all hand disabilities is to obtain the best possible function This may take many months, but in most cases if it is at all possible for the patient to have treatment for the period of time needed, every effort should be made to do so If, for example, a man sustains an injury to the median nerve at the wrist, and he is a skilled workman, such as a motor mechanic, it is essential that he should be rehabilitated back to his skilled occupation While he can well return to some form of work quite soon after nerve suture, he will be most unlikely to earn anything like the amount he was getting in his skilled occupation Consequently, such a patient is advised to remain under full-time treatment until the best possible result is obtained If, after the appropriate time has elapsed, it is clear that function is not going to be adequate for his skill, then is the time to consider a change of job or re-training

Where possible, resettlement should be devised to utilize the patient's experience and knowledge Thus, a bench fitter whose disability prevents him from carrying out the fine work required, can, if he is in other ways suitable, be employed as an inspector or supervisor In large firms and organizations these problems are fairly easily solved, but in the smaller firms such a patient may be impossible to

assimilate, and unless re-training is advised, the best prospect of satisfactory resettlement is in the personal contact of an enlightened D R O with local firms At the other extreme is the case of an engine driver who was able to return to work within a few weeks after secondary suture of the median and ulnar nerves at the wrist, attending daily for physiotherapy (Glanville, personal communication).

Cases where disability is permanent and static, such as paralysis following poliomyelitis or residual impairment after paralysis, fractures, burns, and so on, present few problems that cannot eventually be overcome with the organization and help described in this chapter Patients in the paralysed stage of nerve injuries, or during an extensive programme of reconstructive surgery, can be more difficult, but here resettlement is best postponed until the ultimate result is seen, or at any rate, is going to be obvious The main difficulty with such patients is that they will be unemployed and drawing National Assistance for a long time In large firms such as Vauxhall or Austin, where there are rehabilitation workshops, patients can return to productive work, but this is impracticable for patients in small firms

The ideal organization for these patients would seem to be some form of productive workshop conveniently situated near a local industry, and near a hospital, where patients can carry out part-time useful productive work devised where possible to promote active recovery for their disability, and be paid at agreed rates It might not be possible to arrange the work specifically to increase the range of movement in the stiff joints and redevelop weak muscles Following surgery for a severe injury there may be little that a patient can do with that hand for some months He can, however, carry out a multitude of useful jobs with the good hand, and even coarse movements with the affected hand improve the circulation

There are many difficulties in the way of providing temporary employment for a disabled person, and the setting up of such workshops, carefully supervised by the medical staff of the hospital, might provide the answer

There is certainly a great need for some organization that will allow a patient with a severe hand disability or, indeed, any disability that is going to take time to improve, to carry out some useful work and be paid for it Otherwise there is a great temptation for such patients to take up unskilled work, which may militate against their recovery, in order to make ends meet

Furthermore, the therapeutic value of productive work cannot be overstressed The longer a patient remains away from his work, the more difficult it is for him to acclimatize himself on his eventual return The most difficult of all cases are those in which the disability is remittent and liable to flare up at unpredictable intervals, a good example of this being rheumatoid arthritis All that has already been said about the principles of good resettlement apply even more to this condition

A very special effort must be made to explain to employers the liability of the patient to have relapses from time to time

The patient can help himself with such simple means as having a wax bath at home and keeping at the peak of physical fitness all the time

Each case presents its own problems but much can be done to help the patient if the employer will consider altering chairs, benches, and so on, to suit the

individual deformity, and fixing larger operating handles or grips to industrial tools

Fortunately, the function is usually much bette than the deformity would seem to allow, and it is not so much the hand disability as the general condition of the patient that causes him to miss work

As Cooksey and Brewerton (1956) pointed out, there is clearly no easy answer to these problems Close co-operation between the doctors and employment officials leading to an understanding of the difficulties of patients offers the best hope For many cases sheltered employment is the only course open In others, the patient may at some times be able to work normally, and at others unable to work at all, and it is in this type of case in particular that regular review at the resettlement clinics is of special value

PRINCIPLES OF RESETTLEMENT IN PARTICULAR HAND DISABILITIES

Those with most experience of assessing and placing disabled persons in industry are agreed that the main sub-division of trades to be considered is into clerical and non-clerical

Whenever educational standa-ds allow, a person with an imperfect hand is encouraged to take up clerical work The Ministry of Labour, on the advice of its units, is able to arrange for clerical training either at a Government training centre or at a residential or technical college

In the case of the master hand being unaffected, all clerical duties are possible, the affected hand being used as a support So many industrial activities require use of both hands at some stage, whether for fine work or coarse power, that a patient with an imperfect hand is much more likely to achieve satisfactory resettlement in a clerical grade

Clerical work is divided into commercial and industrial Commercial work comprises such activities as book-keeping and typing Industrial clerical work includes store-keeping, store-checking, and telephone operating All these activities command reasonable pay and offer, in most cases, long-term security—an important consideration with disabled persons

If educational standards are low and manual industrial work is impossible, such work as time-keeping, where integrity of character and reliability are demanded, responsible messenger work, security, checking and inspection are well worth consideration

Patients with artistic abilities wishing to employ them in commercial art, dress designing, and so on, should be dissuaded whenever possible on setting their hearts on such a future The prospects of placing are very poor and experience of I R U s and D R O s in general shows that they very rarely do well If a patient is keen on interior decorating, for example, it is better to advise him to take a course in painting and decorating This ensures him a livelihood and may lead later to an artistic opening

If clerical work is not possible, through lack of background, employment or physical disability, placing in industry is then considered

Industrial trades are divided into skilled, semi-skilled, and unskilled The skilled worker who meets with a severe hand disability is always easier to resettle

than the unskilled man He is more able to learn compensatory tricks at his job and can deploy his experience and intelligence to overcoming difficulties as he meets them The innate adaptability which is a main feature of a skilled worker sees him over many of the hurdles throughout the period of rehabilitation A patient, for example, with engineering ability and experience whose disability prevents him from performing the many skilled movements of the upper limb required in engineering trades is well resettled in the drawing office if his mathematics can be or are up to the required standard It is important for the patient to be training, if possible, for his future job In most cases this can only take the form of preparation for the job, perhaps in a very simple way

It is essential to effect a proper liaison between the future employer or training centre and the patient and his medical advisers early on in rehabilitation Patients can then be guided into the right channels of preparatory work—the embryo draughtsman can study trigonometry, the radio enthusiast circuit diagrams Patients must be strongly advised against wasting time on correspondence courses which they have taken up on their own initiative, as too often their trade rules may not allow them employment There are very few areas in Great Britain where commercial and technical colleges are not available for part-time study It is incumbent on the patient's doctor to advise him in the strongest terms of the benefit in preparing himself for his future If, indeed, it is not feasible so to do, at the least the patient can improve his general education and general knowledge by reading, attending evening classes, intelligent and selective listening and viewing

It cannot be over-emphasized how much a positive approach to the future, and using enforced time off work to best advantage, promotes recovery

Above all, resettlement should never be hurried, the more skilled the worker, the more important for his future happiness, and the country's good, that he should return to as skilled work as possible Long-term rehabilitation should be accepted as ultimately the most economic answer to severe disablement

The three major considerations in assessing a patient's abilities for industrial work are fine finger control, sensibility and power of grip

Although each patient must always be treated as an individual and as a unique problem, and some patients through courage and perseverance are capable of surprisingly skilled work with severe disability, yet for the general run of people the following principles apply

Loss of control

Loss of fine finger control and loss of sensation go together A patient with a motor palsy of the ulnar nerve and one with sensory loss in the median nerve are equally handicapped for fine work Such patients cannot carry out high-class assembly work—they are incapable of holding one part of a machine steady while manipulating other parts Repairs and watch and clock repairing are impossible, as are instrument making and repairing They may, of course, be able to carry out the majority of processes in a task involving coarse grip and movements, but the fine work such as insertion of small screws and split pins proves impossible

Loss of sensation

Loss of sensation in the hand generally rules out all the electrical trades, and those trades where extremes of heat and cold are unavoidable It must be remem-

bered that cold as well as heat is dangerous to a person with loss of sensation, and such activities as refrigeration engineering are contra-indicated Coarse fitting, however, is possible as the affected hand can be used as control, or for follow-through action Drills can be operated and much automatic machine work is possible

Loss of movement of fingers

Any fine work is difficult if there is loss of movement in the finger joints Manipulation of tweezers, delicate work in watch and clock repairing, radio repair and assembling, all demand virtually full movement in the interphalangeal joints

Following tendon grafting, movement in the distal interphalangeal joint may sometimes be limited, but the patient may be able to bring his finger down to the palm This movement is essential for gripping such machines as presses and drills, and is therefore to be encouraged despite lack of progress at the terminal joint

Loss of movement and power in the little finger seriously restricts the gripping of tools such as hammers The little and ring fingers are vital for the general balance of the hand

Loss of grip

Loss of grip is a serious disability If fine finger control and sensation are present, the disability is less serious, and patients can be resettled fairly easily if they have the capacity to be skilled workers Such activities as draughtsmanship, light assembly work, even some types of instrument making, are possible

Loss of grip with loss of dexterity, or loss of grip in an unskilled worker, considerably restricts placing Efforts must be made to adapt machinery by the use of springs or power operated devices to minimize the force necessary on the part of the operator to work the machine Here again a wide field of research is open in the adaptation of machinery to the disabled patient in industry

Stiff hand

When the hand is stiff—for example, after crush injuries, severe burns, long-standing oedema—machinery can be altered to accommodate the restricted movement of the hand Such patients can pull presses with a hook action, can grip handles, particularly if the size of handle can be altered, and can indulge in spray painting and electric welding

Patients with stiff hands can often operate simple types of machine, in such cases assessment by a competent engineer used to disabled people is invaluable

Electric welding is a trade that can successfully be performed with a gross degree of hand damage In fact, patients with only one arm, and some with no hands, have been satisfactorily placed as electric welders

Loss of digits

Loss of the index finger or thumb, or both, restricts activity to coarse grip or use of the hand to guide and control Such patients can press, drill, weld, engrave, and paint and decorate, hanging the paint pot over the affected arm However, any person with any degree of damage to the hand should not be allowed to work on heights The danger of falling without the control and balance given by the hand is ever present

Rheumatoid arthritis

The rheumatoid hand presents grave problems, so much depends on associated joint involvement and the general state of health Patients with severe degrees of rheumatoid involvement of the hands have successfully managed trades which include scientific glass blowing (where the hands are used only for control and turning the glass), clerical and stores work, light drilling, light machine work and manipulation of machinery by foot presses

The attention to the individual problem, and the exercise of ingenuity to adaptations to machinery are all important in this disease

In industrial placing of the disabled in general, staged resettlement is most useful If a patient is incapable of fine work or machine operating, it may be that some months working in the factory on simpler activities may lead to development of ability to cope with more complex activities Assembly work may lead gradually to machine operating This may be due to natural remission of disease, regaining of confidence by the patient, actual improvement in the physical state by the work itself, or the effect in general of work on the disability This is somewhat neglected by doctors, but industrial medical officers vouch for the remarkable therapeutic effects of gainful employment on physical disability

Wilkinson (personal communication) is impressed by the effect of work on diminishing relapses in rheumatoid arthritis, epilepsy, head injury and organic nervous diseases

Spastic hand

Patients with a spastic hand cannot operate machines requiring turning, nor are they capable of skilled work with the affected hand Usually the affected hand can be used as a support, though tremor may be a drawback—fine movements are impossible They can often undertake simple work like sandpapering or sweeping Much depends on associated brain damage with mental effects and speech disability, and it must not be forgotten how greatly the emotional handicap of fear of losing a job may aggravate symptoms A sense of security is thus vital in employment of such patients

In conclusion, it cannot be overstressed that as resettlement is an integral and logical part of rehabilitation, and as the doctor is the overall director of the team, his must be the ultimate responsibility for seeing that his disabled patients resume their rightful place in society

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